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Research Article

Response of maize (*Zea mays*) yield to traditional, conventional, and conservation agricultural practices

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Abstract

Traditional agriculture has had negative effects on crop productivity, food security, and nutrition for many years. The main objective of this study was to compare the effects of conservation tillage with conventional and traditional tillages on maize yield and sandy soil properties at Arba Minch Zuria and Gacho Baba Woredas of Gamo Zone. This study revealed that most of the soil properties are influenced by soil management practices. The soil fertility elements such as OC, TN, and CEC were found to be low in studied soils before and after planting. "Below Optimum" (very low, low, medium) levels of nutrients such as TN, OC/OM, exchangeable bases, CEC, and PBS were found to be low in studied soils; considered deficient and limit crop yield. These limiting nutrients do not allow the full expression of other nutrients that are available in optimum amounts. Multi-nutrient deficiencies in soils have led to a decline in productivity and deterioration in the quantity and quality of the produce. "Optimum" (sufficient, adequate, proportional) nutrient levels are considered adequate and will probably not limit crop growth. "Above Optimum" (high, very high, and excessive) levels of nutrients were considered more than adequate and will not limit crop yield. P_2O_5 and, K_2O are above high and not considered as a yield-limiting mineral elements. CA fields increased maize yield by 39%, and 59% as compared to the CO and TR Fields in the year 2019, respectively). Similarly, CA fields increased maize yield by 54%, and 62% as compared to the CO and TR in the year 2020, respectively. Therefore, it might be advised to use management techniques that improve soil nitrogen availability. Rotation and intercropping of suitable leguminous species that contribute N to the system are also necessary, but the soils in the study area need to be Rhizobium-host-required before any specific recommendations can be made.

Keywords: Conservation; Conventional tillages; Limiting factor; Soil properties; Traditional tillages

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1. Introduction

Agriculture is the mainstay of the Ethiopian economy and the main employment sector for about 80% of the country's population (Njeru et al., 2016). The sector is dominated by smallholder farming and 95% of the land is cultivated by smallholders to generate the key share of total production for the main crops (Taffesse et al., 2012). Of the total tilled land, 90% is ploughed using backward technology and produced main crops (e.g., cereals, pulses, oilseeds, vegetables, root crops, fruits, and cash crops) (Gelaw, 2017). However, smallholder farms are facing various constraints that hamper crop productivity including unscientific cultivation, soil erosions, poor soil fertility, erratic and variable rainfall, and flooding (IFPRI, 2010; Gebregziabher et al., 2006; Zerssa et al., 2021).

Conservation agriculture's (CA) underlying three principles, minimal soil disturbance, soil cover and crop rotation, are increasingly recognized as technology (Coughenour & Chamala, 2000). CA is a way of farming that conserves, improves, and ensures efficient use of natural resources. CA is a farming concept that aims to gain acceptable profit through high and sustained production levels by conserving the key resources of soil and water (Coughenour & Chamala, 2000; Kassam et al., 2009). Those practices make soil retain nutrients better than conventional agriculture practices, that reduce soil erosion, increase water absorption and generate higher and more stable yields (Kassam et al., 2009). It boosts productivity and contributes to reduce land degradation and increase food security.

Conservation agriculture aims to help farmers achieve profits with sustained production levels while conserving the environment. Mulching residue management can increase soil fertility and the availability of nutrients and water to plants (Coughenour & Chamala, 2000). Improved water availability throughout the cropping cycle is another key mechanism of yield improvement. CA keeps the sustainability of nutrients in the soil, which leads to higher and more stable yields (Kassam et al., 2009). CA addresses several key constraints such as: reducing farm labor requirements; sustaining the natural resource base (by reversing land degradation, re-building of soil health through a build-up of soil organic matter (SOM) through minimum soil disturbance and soil cover/cover crops); contributing to mitigating the effects of climate change; and reducing the vulnerability of farm incomes.

Tillage is an effective farm activity to improve soil tilth and soil physical conditions (Khan et al., 2010), which increased nutrient use efficiency of crops and eventually leads to good crop yield (Arif et al., 2007). Numerous factors, such as attack of pests, diseases, seasonal changes, and irrigation hampered the yield of maize but tillage is most imperative factor among them (Rosner et al., 2008). Tillage activities have also a positive effect on soil organic matter (SOM) content (Tian et al., 2016), as it can increase aeration of the soil, help in the decomposition of residue, organic nitrogen mineralization and availability of nitrogen to plants for use (Dinnes et al., 2002). CA (no till and reduced tillage with mulching practices) leads to positive changes in the physical, chemical and biological properties of soil (Bescansa et al., 2006). Soil physical properties that are influenced by conservation tillage include bulk density, infiltration and water retention (Osunbitan et al., 2004). Improved infiltration of rainwater into the soil potentially increases water availability to plants, reduces surface runoff and improves groundwater recharge (Lipic et al., 2005). Reduced soil cultivation decreases farm energy requirements and overall farming costs as less area has to be tilled (Monzon et al., 2006).

The study area is under the escarpments of Rift Valley, in which soil erosion and related problems are very serious. The escarpments of Rift Valley are among the most severely erosion-affected area in Ethiopia along with rates estimated at 10-13 mm/annum on average (IFPRI, 2010). Since erosive storms, rugged topography and mountainous geomorphic features are the most cardinal natural causes of accelerated soil erosion and decrease in soil fertility. The steep and dissected terrain with extensive areas of slopes of over 15% has accelerated soil erosion reaching up to 400 tons/ha/annum (IFPRI, 2010).

There are diverse ranges of soil-related problems that limit the crop production in the study area are following: rainfall variability- in amount and distribution which cause drought/moisture stress, delayed planting date and end season drought; extreme weather phenomena, dry spells and heavy rains, causing flooding, water logging and siltation of sediments in the lower watercourse, and the competing uses for crop residues and manure as livestock feed and fuel, respectively cause severe OM depletion in soils. Even on the cool plateaus where good volcanic soils are found in abundance, crude means of cultivation have exposed the soils to heavy seasonal rain that causes extensive gully and sheet erosion. On average, there is a loss of 200 kg/ha/year of OM, 30 kg/ha/year of N and 75 kg/ha/year of P. The corresponding values of loss for OM, N and P from 780,000 km^2 of land would be 15.6, 2.16 and 5.85 million tons/year, respectively (IFPRI, 2010).

In this study area, crop production systems are based mainly on intensive and continuous soil tillage which has led to a high level of soil degradation and infertility. The unscientific cultivation on the steep slopes without appropriate soil and water conservation measures is causing severe soil erosion and land degradation. The soils are losing the fertile topsoil and facing a reduction in soil depth. Deforestation, unselective grazing of the pasture and marginal lands are some other human-influenced factors of widespread land degradation in the country. The specific objectives were to assess how different tillage techniques affected maize yield and to identify any gaps or potential obstacles to boosting crop production in Arba Minch Zuria and Gacho Baba Districts of Gamo Zone, Southern Ethiopia.

2. Materials and Methods

2.1 Agroecology, climate and description of the study area

An experiment was initiated to investigate the effect of conservation, conventional and traditional tillage practices on maize (Zea mays L) yield and sandy soil properties at target areas of Spiritan Community Out Reach in Ethiopia (SCORE) at Paraso (Demo 1), Ochollo (Demo 2), Bakole (Demo 3) Meiche (Demo 4) in Arba Minch Zuria and Gacho Baba Districts of Gamo Zone, Southern Ethiopia.

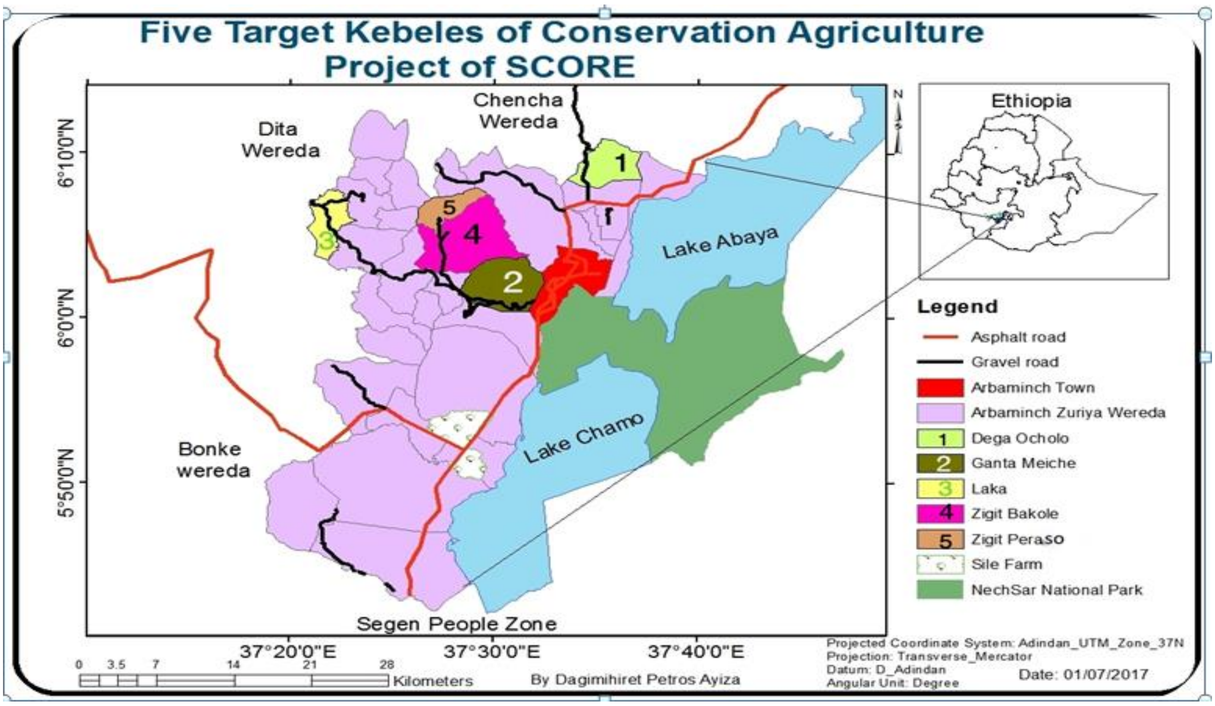

Figure 1. Map of the study area, 2020

According to the Climate classification of Ethiopia, Paraso, Ochollo, Bakole and Meiche are under temperate (Woyina Dega) whereas Laka is under cool temperate (Dega). Since Altitude 2300-3300 meter above sea level (m.a.s.l,) is cool temperate (Dega) and 1500- 2300 m.a.s.l is temperate (Woyina Dega) (Table 1). The catchment has a mid-temperate and temperate climate with highly variable rainfall that is further exacerbated by unfavorable climate change. So that cool temperate is not favorable for maize crop.

Table 1. Based on altitude, climatic classification of the study area, 2020

Data collected	Altitude (m)	Description	Local name
Elevation records between 2330- 2941 m.a.s.l	2300- 3300	Cool temperate	Dega
Elevation records between 1798- 2270 m.a.s.l	1500- 2300	temperate	Woina-Dega

*This climatic classification criterion was based on the Climatic Classification of Ethiopia, 2020

2.2 Soil sampling and laboratory analysis

Soil samples were air dried and passed through a 2-mm sieve, processed, and analyzed for determination of physical and chemical characteristics in Arba Minch University Soil Laboratory, 2019. Particle size analysis was carried out by the modified sedimentation hydrometer procedure

(Bouyoucos 1962). Bulk density was determined by using the core-sampling method (BSI, 1975). Total porosity was estimated from the bulk and particle densities. Particle size distribution was determined by the hydrometer method following Day (1965) procedure. The pH of the soils was determined in H_2O (pH-H_2O) using a 1:2.5 soil to solution ratio using a pH meter as outlined by Van Reeuwijk (Van Reeuwijk, 2002).

Organic matter content of the soil was determined using the wet combustion method of Walkley and Black as outlined by Van Ranst et al. (1999). Soil TN was analyzed by the wet oxidation procedure of the Kjeldahl method (Bremner & Mulvaney 1982). The P_2O_5 contents of the soils were analyzed using the Olsen sodium bicarbonate extraction solution (pH 8.5) method as outlined by Van Reeuwijk (2002), and the amount of P_2O_5 was determined by spectrophotometer at 882 nm and available potassium. Exchangeable basic cations and the CEC of the soils were determined by using the 1M ammonium acetate (pH 7) method according to the percolation tube procedure (Van Reeuwijk, 2002).

Surface soil samples (0–20 cm depth) were randomly collected from 40 soil samples from 4 Demo sites (=4 composites) following the standard procedures of composite soil sample collection. The location of soil sampling sites was marked on the base map on the 1:50,000 scale. The soil samples were processed and analyzed for all aforementioned parameters. Comparative evaluation of CA with CO and TR agricultures of yield comparison trial were practiced and designated as field layout of 5m-by-5m plot with 3 replications.

2.3. Major field activities at demo sites were

The major field activities conducted at the demonstration sites involved three tillage practices: Conservation Agriculture (CA), Conventional Tillage (CO), and Traditional Tillage (TR). Under the Conservation Agriculture approach, minimum tillage was practiced, with land tilled only once. Mulching was applied to maintain 60–80% soil cover, which has been shown to reduce soil loss by 90–100% (Holland, 2004). Weed management was carried out manually, with hand digging performed more than three times. Additionally, chemical fertilizer (NPS) was applied at the recommended rate.

In the Conventional Tillage plots, the land was tilled four times to a depth of 20–30 cm using a hoe, which involved inversion tillage and the complete removal of crop residues before sowing maize seeds. No mulching was applied, resulting in 0% soil cover. Weed control was also done manually using a hoe, with more than three weeding sessions. As with the CA plots, chemical fertilizer (NPS) was applied at the recommended dosage.

For the Traditional Tillage treatment, the land was tilled twice to a depth of 10–20 cm to prepare for sowing. Weed management was conducted using a hoe, with more than two weeding sessions. A small amount of mulching was present, consisting of less than 20% residue from the previous year before tillage. Unlike the other treatments, animal manure was applied at the recommended rate of 10 tons per hectare.

2.4. Statistical analysis

Randomized Complete Block Design (RCBD) was used for the selected soil physicochemical properties. A minimum of three replicates per treatment were implemented. Data analysis was carried out using SAS 9.2 Version System (SAS, 2008) to compare the effects of different treatments on tillage and maize (*Zea mays*) yield.

3. Results and Discussion

3.1 Environmental settings and land physiography of the study areas

The studied area is under the escarpments of Rift Valley, which is severely affected by erosion. Erosive storms, rugged topography and mountainous geomorphic features are the most cardinal natural phenomenon in the study area. As a result, these soils are poor and highly vulnerable to erosion. Slope of the study area are 11.36% (Paraso), 7.65% (Ochollo), 7.65% (Bakole) and 8.33% (Meiche). The slope gradients are rated as: Flat (<5%); Gentle (6- 15%);

Table 2. Land physiography, location data and soil texture of the study area, 2019

Site	Land Utility	Altitude (m)	Latitude	Longitude	Surf. Stone	Erosion	Slope (%)	Sand (%)	Silt (%)	Clay (%)	Textural Class
Paraso	Maize	2163	6°6`9``	37°27`16``	2 (S1)	M	11.4 (S3)	64.8	23.2	12	Sandy (S3)
Ocholo	Maize	2009	6°9`22``	37°35`22``	2 (S1)	M	7.7 (S2)	73.6	15.1	11.3	Sandy (S3)
Bakole	Maize	2260	6°5`14``	37°27`16``	2 (S1)	M	7.7 (S2)	77.5	11	11.5	Sandy (S3)
Merchie	Maize	2216	6°1`29``	37°29`10`	4 (S2)	M	8.3 (S3)	80	9.3	10.7	Sandy (S3)

S1= Very favorable, S2= Favorable, S3= Unfavorable for agriculture= Slope gradients are rated as in eight classes (0-0.5%, 0.5-2%, 2-5%, 5-8%, 8-16%, 16-30%, 30-45%, and >45% slopes), Demo=Demonstration site

Steep/Mountains (>15%). Erosion susceptibility and past erosion damages were moderate hazard levels for placing soils (Table 2). The steep and dissected terrain over 15% of slopes with extensive areas are dominant features in the study area; which has accelerated soil erosion reaching up to 400 tons/ha/annum (IFPRI, 2010). Crude means of cultivation have exposed the soils to heavy seasonal rain that causes extensive gully and sheet erosion.

There has high runoff and good drainage, probably due to the slope of the landscape position, depth and its sandiness of the soil (Table 2). In the escarpment between lowland and highland catchments, the scattered trees were cleared and replaced by the settlement of human population because of a shortage of farmland, absence of other livelihood alternatives to rural-urban migrants, and proliferating rural poverty and unemployment. So that the poor are victims of resource degradation, and the resource depletion becomes worse when it is open access to all with high demand. The erosive storms, rugged topography and mountains geomorphic features are the most cardinal natural causes of accelerated soil erosion and that decreases soil fertility in the study area (Figure 1).

3.2. Effect of conservation, conventional and traditional cultivations on soil characteristics

3.2.1. Soil physical properties

For ease of presentation, soil texture. bulk density and porosity are treated as soil physical properties in this text. Textural classes of surface soils in all Demo sites were sandy (Table 2). Soil texture influences the ease with which water flows through soil and also the soil capacity to hold water. Sandy soils retain less water. Soil texture largely determines the water-holding capacity of a particular soil, and the amount of water is strongly related to the types and numbers of soil organisms that will inhabit and influence soil water availability, these sandy soils typically being relatively low on the SOM which influences plant productivity.

Table 3. Soil quality ratings for bulk density and porosity

Rating	Bulk density (g cm^{-3})[a]	Porosity (%)[b]
Very low	< 1	< 2
Low	1 – 1.3	2 – 5
Moderate	1.3 – 1.6	5 – 15
Moderately high	1.6 – 1.8	15 – 40
Very high	> 1.8	> 40

[a]=Landon (1991), [b]=FAO (2006)

Bulk density (g/cm^3) of all demo sites was in the low range (1-1.3) (Table 3). Porosity (%) of all Demo sites was at a very high range (56.98 - 61.89) (Table 3) which is suitable for crop productivity. Lower bulk density implies greater pore space, improved aeration and increased SOM; creating a choice environment for biological activity. Porosity is itself influenced by the activity of larger soil fauna, and earthworms, ants, cicadas, and many other macro arthropods produce macrospores that are involved in water and gas movements (Jackson et al., 2003). Soils with a high proportion of pore spaces to solids have lower bulk densities than those that are more compact and have less pore space. Therefore, any factor that influences soil pore spaces will affect bulk density. Ratings of soil Texture, bulk density and total porosity are indicated in section 3.2.2.

3.2.2. Soil chemical properties

For ease of presentation, soil pH, OC/OM, TN, P_2O_5, and K_2O are treated as soil chemical properties in this text (Table 4). The soil pH-H_2O values were varied from 5.67 - 6.43 in all Demo sites before planting (Table 3) and rated as slightly acidic to moderately acidic (Tekalign, 1991). After cropping, the surface soil pH-H_2O values were increased in the studied Demo sites. The degree of acidity based on pH is classified as follows: Ultra acidic (<3.3); extremely acidic (3.5 -

4.5); Very strong acidic (4.5 - 5.0); Strong acidic (5.1 - 5.5); moderately acidic (5.6 - 6.0); slightly acidic (6.1 - 6.5); neutral (6.6-7.3) and Slightly Alkaline (7.4-7.8). Most plants grow best at pH above 5.5. Soil pH of around 6.5 is considered optimum for nutrient availability. Soil with low pH contains relatively high exchangeable H^+ and is Al^{3+}considered as acid soil.

Soil organic matter contents of surface soils varied from 2.40 - 4.43% along different Demo sites (Table 4); most of the SOM contents in the studied soils were in low ranges before planting. This indicates that for both CO and TA without the application of nitrogen-containing fertilizers, no adequate yields can be achieved. According to the results of fertilizer trials carried out in Ethiopia, the critical SOM values for the common cereals grown are 2.5% for barley and wheat; 3.0% for maize; 2.0% for sorghum and teff (Bezuneh, 2013). SOM content are categorized as very low (<1%), low (1-2%), medium (2-3%), high (3-5%) and very high (>5%) (Bezuneh, 2013). Also, it is similar to Tekalign's (1991) ratings. SOM has the power to alter and improve the physical, chemical, and biological properties of soils and as a result increase plant productivity (Solaiman et al., 2010).

TN content of all the Demo sites surface soils was low (0.03- 0.13%) (Table 4). It is because of the relatively fast mineralization of nitrogen from the OM that N is a limiting factor for crop production in the study area. The distribution pattern of TN across Demo sites was similar to that of SOM since SOM contents are a good indicator of available nitrogen status in the soil. TN content of soils are categorized as low (< 0.15 %), medium (0.15 - 0.25 %) and high (>0.25 %) (Havlin et al., 1999). Intensive and continuous cultivation aggravated SOC oxidation, resulting in a reduction of TN as compared to ploughed fields.

The C: N ratio of Demo sites were 23.17 to 51.33 before planting (Table 4), which is at a moderate level as compared to the C: N ratio (<20:1) of legume fields with the C: N ratio of wheat and oat straw (=100:1). The recorded C: N ratio status in surveyed sites suggests that the conditions for plant growth moderately favorable. This higher value of C: N ratio is due to the higher content of OC and lowers the content of TN. It is generally accepted that C: N ratios between 8:1 and 12:1 are considered to be the most favorable condition for crop production. This is a low C: N ratio which is commonly obtained from the application of manures and legumes. But high levels of C: N ratio imply relatively fast mineralization of nitrogen from the organic materials.

Available P (Olsen) contents of the Demo site soils were recorded as 20.67- 140.15 mg/kg (Table 4). The Av. P content of the surface soils was relatively higher. The available P (mg/kg) contents of the soils were rated as very low (<5), low (5- 9), medium (10- 17), high (18- 25) and very high (>25) (Havlin et al., 1999).

Table 4. Physicochemical characteristics of the experimental site soil (0–20 cm), 2019- 2020 Soil Characteristics

	BD (g/cm$^{3)}$	Porosity (%)	pH(H_2O) 1:2.5	EC (dS/m)	OC (%)	TN (%)	OM (%)	C:N (ratio)	P_2O_5 (mg/kg)	K $_2$O (g/kg)	CEC (cmol(+)/kg)
Paraso											
Initial	1.1	61.82	6.43	0.10	2.57	0.09	4.43	28.56	26.94	380.94	0.83
Rating	S1	S1	MA	SF	M	L	M	M	H	H	VL
CA	1.06	60.00	7.11	0.15	1.72	0.06	2.94	28.67	112.67	395.36	4.24
Rating	S1	S1	MA	SF	M	L	M	M	VH	VH	VL
CO	1.12	57.74	6.84	0.08	1.68	0.08	2.90	20.00	112.81	400.82	4.96
Rating	S1	S1	MA	SF	L	L	M	H	VH	VH	VL
TA	1.14	56.98	7.24	0.07	1,40	0.07	2.41	20.00	70.68	518.31	4.64
Rating	S1	S1	SA	SF	L	L	L	H	VH	VH	VL
Ocholo											
Initial	1.03	61.13	5.75	0.20	1.54	0.03	2.65	51.33	77.75	499.13	0.61
Rating	S1	S1	N	SF	M	L	M	M	VH	VH	VL
CA	1.02	61.51	6.13	0.27	2.52	0.12	4.34	19.38	140.15	545.63	4.28
Rating	S1	S1	SAI	SF	M	L	M	H	VH	VH	VL
CO	1.04	60.75	7.54	0.27	2.24	0.11	3.86	37.33	111.88	436.34	4.92
Rating	S1	S1	SA	SF	M	L	M	M	VH	VH	VL
TA	1.00	62.26	7.65	0.21	1.68	0.08	2.40	20.00	77.78	474.59	3.30
Rating	S1	S1	N	SF	M	L	L	H	VH	VH	VL
Bakole											
Initial	1.11	58.11	5.87	0.08	1.39	0.06	2.40	23.17	20.67	263.83	0.59
Rating	S1	S1	N	SF	M	L	M	M	H	VH	VL
CA	1.07	59.62	7.05	0.09	1.68	0.08	2.90	20.00	139.26	526.50	3.78
Rating	S1	S1	SAI	SF	M	L	M	H	VH	VH	VL
CO	1.04	60.75	6.17	0.06	1.12	0.06	1.93	18.67	127.48	318.58	2.78
Rating	S1	S1	SA	SF	L	L	L	H	VH	VH	VL
TA	1.04	60.75	6.24	0.06	1.40	0.07	2.41	20.00	136.55	395.36	4;80
Rating	S1	S1	N	SF	L	L	L	H	VH	VH	VL
Merchie											
Initial	1.03	61.13	6.26	0.10	1.48	0.05	2.55	29.60	24.24	487.69	0.58
Rating	S1	S1	N	SF	L	L	M	M	H	VH	VL
CA	1.00	62.26	7.65	0.13	1.68	0.07	2.90	24.00	97.48	545.63	3.78
Rating	S1	S1	SAI	SF	M	L	M	M	VH	VH	VL
CO	1.02	60.75	7.11	0.09	1.40	0.08	2.41	17.50	58.01	324.43	3.34
Rating	S1	S1	SA	SF	L	L	L	H	VH	VH	VL
TA	1.01	61.89	6,95	0.10	1.40	0.07	2.41	20.00	55.08	384.30	2.70
Rating	S1	S1	N	SF	L	L	L	H	VH	VH	VL

L= Low, VL=Very low, M=Moderate, and H= High, MA= Moderately acidic= SA= Slightly acidic, N= Neutral, Sal= Slightly Alkaline, SF= Salt Free (i.e., EC: <2dS/m), %OC x1.724= %OM, pH= Power of hydrogen, OM= Organic matter, TN= Total nitrogen, C: N= Carbon to Nitrogen ratio, Av. P_2O_5= Available phosphorous,1 dS/m= 1000 µS/cm

Higher P values of surface soils might be attributed to a slightly preferred range of soil pH, low level of Ca in soils, greater diffusion of P in moist soil conditions (since soil and water conservation prevalent at the study site), the mineralization of OM, and difference in land use management. Based on the above results it is not compulsory to apply P_2O_5 containing fertilizers in all of the Demo sites.

Available K content of the surface soils in the Demo sites were ranged from 263.83 - 545.63 gKg^{-1} (Table 4), which is a medium to very high range. The CA mulches were increased the accumulation of soil K because the nutrient-rich branches and coarse litter fraction are all-important nutrient sources. The Available K content in (gKg^{-1}) can be rated as very low (<120), low (121- 240), medium (241-300), high (300- 360) and very high (>360), which has been supported by Tandon (2005).

The CEC of the surface soils ranged from 0.58 to 4.96 cmol (+) kg^{-1} of soil (Table 4), which is a very low range. The CEC in (cmol (+) Kg^{-1}) can be rated as very low (<6), low (6- 12), medium (12- 25), high (25- 40) and very high (>40) (Hazelton and Murphy, 2007). The lower the CEC in surface soils, the less capable the soil can retain mineral elements. Soils with a low CEC are more likely to develop deficiencies in K^+, Mg^{2+} and other cations while high CEC soils are less susceptible to leaching of these cations (CUCE 2007). The main ions associated with CEC in soils are the exchangeable cations Ca^{2+}, Mg^{2+}, Na^+ and K^+ (Rayment and Higginson 1992), and are generally referred to as the base cations. It is accepted that OM is responsible for 25-90% of the total CEC of surface mineral soils (Oades et al., 1989). The high CEC values have been implicated with high yield in most agricultural soils and CEC values in excess of 10 cmol(+)kg^{-1} are also considered satisfactory for most crops (Nachtergaele, 2010).

3.2.3. Limiting factor(s) for crop production in the study areas

Based on nutrient rating and diagnostic methods (Tuma, 2013), nutrients such as TN, OC/OM and CEC (Table 5) were found to be very low, low and medium in studied soils; i.e., "Below Optimum" nutrient levels were considered deficient and limit crop yield. Specifically, the soil fertility factors such as OC, TN and CEC contents were found to be low in studied soils before and after planting (Table 5) these nutrients are considered as yield-limiting factors for crop production. Nutrient levels (in Table 5) were considered adequate i.e., "Optimum" (sufficient, adequate, proportional) these will probably not limit crop growth and such limiting nutrients do not allow the full expression of other nutrients that are available in optimum amounts (Tuma, 2013). Based on nutrient rating and diagnostic methods, nutrients such as P_2O_5 and K_2O were found to be high, very high to excessive in studied soils; i.e., "Above Optimum" nutrient levels are considered more than adequate and will not limit crop yield; there is the possibility of a negative impact on the crop if additional nutrients are added. CA were improved soil fertility and organic content as compared to CO and TA. This study revealed that most of the soil properties (Table 5) were influenced by soil management practices (CA. CO and TA). Multi-nutrient deficiencies in soils have led to a decline in productivity and deterioration in the quantity and quality of the produce.

Table 5. Nutrient index levels, expected relative yield without fertilizer, and implications for crop fertilization (Zebire et al., 2029)

Nutrient index ievel	Expected relative yield without fertilizer (%)	Meaning of nutrient index level for crops Applying the nutrient will be beneficial
Very low	<50	Over 80% of the time
Low	50-80	65% of the time
Optimum	80-100	5% of the time
High	100	<1% of the time

3.3. Effect of conservation, conventional and traditional agricultural practices on yield of maize

Grain yield is the final objective of farmers. Maximum maize (*Zea mays*) grain yield (7973 Kgha^{-1}) was noted in CA fields (Table 6), which showed statistical differ significantly ($P<0.05$) with CO and TA. The lowest grain yield (600Kgha^{-1}) was found in TA practice, which shows that grain yield was (7.53%) higher in CA soils over TA soil and statistical differ significantly ($P<0.05$) with CA and CO. The average maize yield of CO (kg/ha) was in moderate level as compared to TA (Table 6), and the relative advantage obtained from CO was apparent. Because maize yields of CA were highly significant as compared to maize crop yields of both CO and TA. CA tillage had substantially suppressed weed development in the experimental sites.CA fields increased maize yield by 39%, and 59% as compared to the CO and TR fields in the year 2019, respectively (Table 4), though there were no large differences among the practices of CO and TR. Similarly, CA fields increased maize yield by 54%, and 62% as compared to the CO and TR Fields in the year 2020, respectively (Table 6), though there were no large differences among the practices.

A comparative analysis of CA fields in two years (2019 and 2020) was increased maize yield by 37%. The rainfall during the Belge season of 2020 was unreliable. Recent studies have reported that CA improved crop productivity by 20–120% and water productivity by 10–40% (Patil et al, 2016). The finding of Zhang et al. (2015), found that grain yield was (4.4%) higher in CA soils over CO soil. Cultivations have the most direct consequences on soil erosion. No-till systems leave virtually the entire residue on the soil surface, providing up to 100% cover and nearly eliminating erosion losses (Holland, 2004).

A comparative analysis of the returns on investment in CO and CA in Kenya showed a potential of doubling benefits by using CA (Kaumbutho & Kienzle, 2007). Weeds are smothered due to soil cover with residues, leading to labor saving in weed control. A comparative analysis of the returns on investment in conventional agriculture and CA in Kenya showed a potential of doubling benefits by using CA (Kaumbutho & Kienzle, 2007). The CA (reduced tillage with mulching practices) lead to positive changes in the physical, chemical and biological properties of soil (Bescansa et al., 2006)

Table 6. Harvested grain yield (maize yield (kg/ha)), 2020

Maize yield (Kg/ha) in year 2019												
Site	CA-A	CA-B	CA-C	Mean	CO-A	CO-B	CO-C	mean	TR-A	TR-B	TR-C	mean
Peraso	11600	5520	6800	7973^{a}	4560	4200	4080	4280^{bc}	2640	2200	1280	2040^{d}
Ocholo	6520	6080	4080	5560^{bc}	2160	2200	1840	2067^{d}	3560	3600	4880	3880^{c}
Bakole	4160	3920	3800	3960^{c}	1440	2080	1840	1787^{d}	1800	2200	1920	1987^{d}
Meyche	5800	6480	5360	5880^{b}	2240	2600	1280	2040^{d}	1600	1840	1380	1620^{d}
Average				5843				2584				2382
Maize yield (Kg/ha) in year 2020												
Peraso	1800	4800	3840	3480^{ab}	2500	2000	1680	2060^{c}	1600	1680	1520	1600^{c}
Ocholo	4200	4000	3400	3867^{a}	1800	1680	1600	1693^{c}	2120	2000	1880	2000^{c}
Bakole	3400	3000	2600	3000^{b}	1760	1400	1200	1453^{cd}	1680	1260	1320	1420^{cd}
Meyche	4080	4560	4200	4280^{a}	1440	1640	1600	1560^{c}	600	640	560	600d
Average				3657				1692				1405

Values with different letters in a column differ significantly at $P < 0.05$, CA= Conservation tillage, CO= Conventional tillage, TR= Traditional tillage= A, B, C are replications

Maize grain yields were significantly influenced under various cultivations (Table 7). Comparison of three tillage practices in maize experimental sites; i.e., maize grain yield was positively and significantly ($P < 0.01$) affected by CA as compared to CO and TR (Table 7). Maize under CA had better grain yield and significantly higher than grain yields obtained from CO and TA, respectively (Table 6). The use of mulch and zero till in CA fields were increased maize grain yield and considered as source of fertilizer for better maize crop productivity (Coughenour & Chamala, 2000; Kassam et al., 2009). Maize under CA had better adaptation due to reduced runoff, increased OC/OM, improved soil physicochemical properties, increased soil fertility, increased resistance to drought, escaped from water stress, reduced weeds and reduced incidence of pests and diseases.

In CA fields erosion was reduced, the fertility of the soil was improved, and the runoff water loss was reduced, allowing the crop to have more water in dry periods. Tillage activities have also positive effect on SOM content (Tian et al., 2016), as it can increase aeration of soil, helps in decomposition of residue, organic nitrogen mineralization and availability of nitrogen to plants for use (Dinnes et al., 2002; Rosner et al., 2008).

Conservation agriculture is reported in some studies to increase system diversity and stimulates biological processes in the soil and above the surface, i.e., due to reduced erosion and leaching. The adoption and development of CA tillage lead to a number of benefits in the water supply system within the agricultural ecosystems, such as greater availability of water for the crop. According to Lal (2008), CA is a good strategy not only to mitigate climate change but also to adapt agricultural ecosystems to their effects, by increasing crop resilience facing climatic variations. Mulching in contact with the soil is one of the most effective factors for reducing erosion. For example, a 90% mulch cover reduces erosion by 93% (Wischmeier, 1984). Also, Nill & Lumassegger (1996) reported that a 60 -80% soil cover/mulch cover reduces soil loss by 90-100%. In CA fields, we applied mulch as a component of CA on basis of Nill & Lumassegger (1996). Thus CA had a negative effect on soil loss. Since mulching reduces surface runoff and reduces soil loss during and after rainfall, which increases infiltration and soil fertility. Ground cover slows down the runoff velocity, which increases the flow depth thereby providing a greater buffer for reducing the hydrodynamic impact forces of the raindrop on soil (Mutchler & Young, 1975).

Table 7. Influence of different cultivations on yield of maize, 2019- 2020

Tillage Types	Grain yield (year)	
	2019	2020
CA (Mulch (60-80%))	5843.3[a]	3656.7[a]
CO (No mulch (0%))	2543.3[b]	1691.7[b]
TR (Mulch (<20%))	2408.3[b]	1405.0[b]
LSD	837.85	456.07
CV (%)	26.18	22.78

Values with different letters in a column differ significantly at $P < 0.05$

3.4 Effect of environmental and tillage interaction on grain yield of maize

Grain yield of maize (in 2019) at Peraso was higher and significantly different from other Demo Sites and tillage practices, though there were no significant differences between the Demo Sites of Bakole and Meyche (Table 8). As a result, maize grain yield at Peraso was increased by 39%, and 59% as compared to other Demo Sites. Grain yield of maize (in 2020) at Ocholo was higher and significantly different from other Demo Sites and tillage practices, though there were no significant differences between the Demo Sites of Peraso and Meyche (Table 8). Interaction effects of Demo Sites (Peraso, Ocholo, Bakole and Meyche) over tillage practices (CA, CO and TR) in two years (2019 and 2020) were different because the rainfall during the Belge (winter) season of 2020 was unreliable (Table 2). Cultivations have the most direct consequences on soil erosion. No-till systems leave virtually the entire residue on the soil surface, providing up to 100% cover and nearly eliminating erosion losses (Holland, 2004). For example, recent studies have reported that CA improved crop productivity by 20–120% and water productivity by 10–40% (Patil et al., 2016). The finding of Zhang et al. (2015), found that grain yield was higher in CA soils over CO soil.

Table 8. Environmental and cultivation interaction effect on grain yield of maize, 2019 – 2020

Interaction effect demo sites	Grain yield (year)	
	2019	2020
Peraso	4764.4[a]	2380[ab]
Ocholo	3880a[b]	2520.0[a]
Bakole	2573.3[c]	1957.8[b]
Meyche	3175.6[bc]	2146.7[ab]
LSD	967.47	526.63
CV	26.18	22.78

Values with different letters in a column differ significantly at $P < 0.05$

The study identified several environmental factors that significantly limit agricultural production in the area. One of the most critical challenges is the variability of rainfall, both in amount and distribution, which often leads to moisture stress and negatively impacts crop performance. This irregularity also contributes to delayed planting dates and exposes crops to end-of-season droughts, further reducing yields.

Extreme weather events, including prolonged dry spells and heavy rains, were also noted as major constraints. These conditions result in flooding, waterlogging, and the siltation of sediments in lower watercourses, all of which disrupt farming activities and damage both crops and infrastructure. Such events make it difficult for farmers to maintain consistent production and adapt to changing climatic conditions.

Additionally, the combination of erosive storms, rugged topography, and mountainous geomorphic features was identified as a primary natural cause of accelerated soil erosion. These factors contribute to the rapid loss of fertile topsoil, reduce land productivity, and pose serious long-term threats to sustainable agriculture in the region.

4. Conclusion

Soil test categories could be explained as: *"Below Optimum"* (very low, low and medium) levels of nutrients are considered deficient and will probably limit crop yield. There will have a moderate to a high probability of an economic crop yield response to additions of that nutrient. *"Optimum"* (sufficient, adequate, proportional) levels of nutrients are considered critical/adequate and will probably not limit crop growth. There is a low probability of an economic crop yield response to additions of these nutrients. *"Above Optimum"* (high, very high, and excessive) levels of nutrients are considered more than adequate and will not limit crop yield. There is a very low probability of an economic crop yield response to additions of these nutrients. At very high levels there is the possibility of a negative impact on the crop if nutrients are added. Specifically, the soil fertility factors such as OC/OM, TN, and CEC contents were found to be low (below optimum) in studied soils before and after planting. The limiting nutrients do not allow the full expression of other nutrients that are available in optimum amounts. Therefore, it could be recommended to include management practices that increase nitrogen availability in the study area locations. Furthermore, rotation and intercropping of appropriate leguminous that add N to the system is required, however, Rhizobium-host requirement is required to give concrete recommendation in the study area soils.

Conflict of Interest

There is no conflict of interest, according to the authors.

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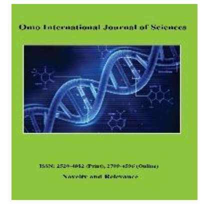

Research Article

Assessment of the prevalence of gestational diabetes mellitus and associated factors among women attending antenatal care at Arba Minch town public health facilities, Southern Ethiopia

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Abstract

Gestational diabetes mellitus (GDM) is a high blood sugar condition that some women acquire during pregnancy which could have devastating effects on both the mother and baby if left untreated. In most of the developing countries including Ethiopia, women are rarely screened for GDM during ANC visits. It was previously estimated that gestational diabetes occurs in four to nine percent of pregnant women in Ethiopia. So, the aim of this study was to assess prevalence of GDM and associated factors among women attending antenatal care at Arba Minch town public health facilities. Institution based cross sectional study design was employed among 380 pregnant women's visiting antenatal care clinic. Women were enrolled if they had fulfilled inclusion criteria during the study period. Data was collected using a pre-test structured interviewer administered questionnaire September 2019 to November, 2019. Descriptive statistics was done. Results were summarized and presented by tables, charts and graphs. The prevalence of GDM was 7.1%. Nearly one-third of the respondents, 247(65%) had two or more pregnancies, with mean gestational age of 25 weeks. Half of the respondents, 187(49.2%) were multi-para. Of 380 pregnant women, 53(13.9%) had previous history of stillbirth. Maternal age, educational level, parity, history of having macrocosmic baby, previous history of GDM and family history of type II DM were associated with GDM. Older ages, low educational level, grand multipara, having macrosomic baby and history of type II diabetes mellitus were factors associated with increased risks of gestational diabetes mellitus. Therefore, to enhance maternal and child health, improving screening, treatment, and prevention strategies for gestational diabetes mellitus is necessary.

Keywords: Diabetes mellitus; Diagnosis; Glucometer; Pregnancy

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1. Introduction

Sub Saharan Africa (SSA) has the highest maternal mortality in the world, with the majority of maternal deaths being attributed to haemorrhage, infections, obstructed labour and hypertension (Khan et al., 2006). Estimated at 676 deaths per 100,000 live births (Hogan et al., 2010), maternal mortality in Ethiopia is more than three times of the worldwide average. Gestational diabetes mellitus (GDM), though it is never listed as a cause of maternal death, significantly increases the risk for all common maternal killers and yet is rarely addressed in resource-constrained settings (ENHAT-CS, 2015).

GDM is a high blood sugar condition that some women acquire during pregnancy and it usually starts halfway through the pregnancy between the 24th and 28th week of pregnancy (Christenson et al., 2001). Placental hormones and increased fat deposits causes insulin resistance during pregnancy which will block insulin action to bind its receptors that is why this condition causes high level of glucose in pregnant women (Carr et al., 1998).

It is a public health problem that currently affects a large part of the female population and has short- and long-term consequences for the fetus and the mother causing macrosomia, preeclampsia, polyhydramnios, fetal macrosomia, birth trauma, perative delivery, neonatal metabolic complications and perinatal death. Development of obesity and diabetes in offspring during childhood and later development of diabetes mellitus in the mother are also related with GDM (Anderson et al., 2003). Approximately 7% of all pregnancies are complicated by GDM, resulting in more than 200,000 worldwide cases annually and the prevalence may range from 1% to 14% of all pregnancies depending on the population studied and the diagnostic tests employed (Kirkman and Schaffner, 2012). Ferrara reported that GDM prevalence has increased by 10 to 100% in several ethnic groups during the past 20 years (Ferrara, 2007).

Gestational diabetes is also becoming a public health concern in Sub-Saharan Africa (SSA). A study in rural South Africa reported a prevalence of GDM of 1.5% and impaired glucose tolerance (IGT) of 7.3% (Mamabolo et al., 2007)). According to WHO 2016 report, more than half of 16, 000 deaths attributable to high blood glucose in Ethiopia were women in reproductive age group (WHO, 2018). In an Ethiopian rural community, GDM prevalence was 3.7% (Seyoum et al., 1999). It was previously estimated that gestational diabetes occurs in four to nine percent of pregnant women in Ethiopia, but these data are scant and old. An estimated 80 percent of cases remain undiagnosed (IDF, 2016).

GDM has to be identified timely in order to avoid risk and complication to the mother and the child. In a developing country like Ethiopia due to proper lack of resources and clinical investigation the pregnant women have to bear serious consequences putting their life at a stake (Bhattarai et al., 2007)). With the current prediction of increasing type 2 diabetes cases, even at a younger age, which could be related to GDM, controlling GDM would be of potential benefit to reduce the health care burden for treating people with type 2 diabetes, which is a costly lifetime condition. The International Diabetes Federation recognizes identification and treatment of GDM as a global priority (IDF, 2016). Therefore, the aim of this study was to assess prevalence GDM and associated factors among women's attending ANC in study area.

2. Materials and Methods

2.1. Description of study areas

Institution based cross sectional study design was conducted from September to November 2020 in Arba Minch town public health facilities, Gamo Zone, Southern Ethiopia in SNNPR. The town consists of estimated total population of 98,000 with an area of 514 sq.kms and located at the altitude of 1200 to 1400 meters above sea level. There are one General Hospital, one Primary Hospital, two health centers, and different level of private health facilities. Among these, Arba Minch General Hospital provides different health services and has a total of 470 beds and more than 400 staffs working in it. The ANC follow up clinic has a total of around 1000 pregnant women who is on the follow up and it gives services to around 40-50 pregnant women per day. The health centers also have ANC follow up clinic.

2.2. Source population

Source populations were all pregnant women who undertook antenatal care follow up service during the study period in Arba Minch General Hospital, Secha and Arba Minch Health centers.

2.3. Study population

The Study populations were selected pregnant women who came to antenatal care service in Arba Minch General Hospital, Secha and Arba Minch Health centers during the period of study. Those pregnant women with lost chart, incomplete information, who were unable to respond and who were less than eighteen years of age were excluded from the study.

2.4. Sample size determination

Sample size was determined by using single population proportion formula taken from research done on prevalence of Gestation Diabetes Mellitus among Pregnant Women in Tigray region is 13 % (ENHAT-CS, 2015). Assuming 5% degree of precision or margin of error, 95% confidence interval, and 10% non-response rate, the final sample size was 383.

2.5. Sampling procedures

To achieve the desired sample size, all pregnant women who came for antenatal care were selected by systematic random sampling method until the required sample size was met during the study period. Equal number of sample size was selected from Arba Minch Genral Hospital, Secha and Arba Minch Health centers. By dividing the total source population to study population, the k value is 4.

2.6. Operational definition

Gestational diabetes mellitus is a glucose intolerance with onset or first recognition during pregnancy with fasting 5.1-6.9 mmol/L or 1hr: ≥10.0 mmol/L or 2 hr: 8.5-11.0 mmol/L. Glucose intolerance is a pre diabetic state of hyperglycemia that is associated with insulin resistance and increase risk of cardio vascular pathology.

2.7. Method of data collection and instrument

The data were collected using semi-structured interviewer administered questionnaire adapted from previous studies. The questionnaire was further modified after a pretest on other similar population undertaking 5 % of the total sample size outside the study area. The questionnaire was original prepared in English and translated to Amharic. It was further translated back from Amharic to English and comparisons were made on the consistency of the two versions. Two days training was given for data collectors and a supervisor. Blood samples were collected from each respondent and tested for random blood glucose in each public health facilities laboratory by following standard methods. About 75 gm oral glucose administered, capillary glucose level was measured at 0hr and 2hr using HemoCue Glucose and GDM was diagnosed based on revised WHO criteria.

2.8. Data processing and analysis

Data were entered, coded, and cleaned after checking for completeness and consistency, into EpiData version 3.1 and exported to SPSS version 21.0 software for analysis. Mean, median and standard deviation were calculated for continuous variables whereas proportion was calculated for categorical variables. Results were summarized and presented in tables, charts and graphs. Chi-square test was also used to see the association between variables.

3. Results

3.1. Socio-demographic characteristics

The data were collected from 380 pregnant women giving a response rate of 99%. About 217 (57.1%) of them were aged below 25 years and 26 (6.8%) were aged greater than 35 years (Table 1). Majority of the respondents, 325 (85.5%) were married, 10 (2.6%) were not married, 4 (1.0%) were widowed and the rest 11 (3.0%) were divorced.

Table 1. Socio-demographic characteristics of pregnant women who attend antenatal care service in public health institutions in Arba Minch town, Southern Ethiopia, 2020

Variables	Category	Frequency (n)	Percent (%)
Maternal Age	18-25	2	57.1
	26-35	1	36.0
	>35	2	6.8
Religion	Orthodox	2	71.6
	Protestant	9	24.2
	Others*	1	4.2
Occupation	Housewife	1	42.4
	Governmental employee	1	33.2
	Student	4	11.6
	Merchant	3	8.4
	Others**	1	4.4
Marital Status	Married	3	85.5
	Not married	4	10.5
	Widowed	4	1.0
	Divorced	1	3.0
Educational Level	No formal education	1	32.6
	Primary	1	34.2
	Secondary	5	13.2
	College and above	7	20
Family size	Up to 5 members	2	71.1
	>5 members	1	28.9
Family income	500 birr or less	2	54.7
	>500 birr	1	45.3

*=Muslims, catholic, adventist, **=Farmer, private

Most of, 130 (34.2%) study participants attended primary education and 76 (20%) participants educational level was college level and above. Concerning their family size, 210 (55.3%) of the study participants lived in families of more than five members while the rest 270 (71.1%) lived in families of five or less members.

3.2. Lifestyle and behavioral characteristics

Out of the total respondents, 285 (75%) engaged in low level physical activity, 81 (21.3%) performed moderate physical activity and the rest 14 (3.7%) participants had intensive physical activity experience. Of the 380 study participants, 64 (16.8%) of mothers had no history of alcohol intake while 9 (2.4%) were smokers. Majority of pregnant women in the study had history of coffee intake. History of chat chewing was also reported among 19 (5%) of participants.

Table 2: Table 2: Selected obstetric and medical history of pregnant women who attend antenatal care service in public health institutions in Arba Minch town, Southern Ethiopia, 2020.

Characteristics	**Categories**	**Frequency (n)**	**Percent (%)**
Gestational age in weeks	20	74	19.5
	24	56	14.7
	28	68	17.9
	32	83	21.8
	36	99	26.1
Parity	Nulliparous	64	16.8
	Primipara	69	18.2
	Multipara (2-4)	194	51.1
	Grand multipara (>5)	53	13.9
Gravidity	Primigravida	61	16.1
	Multigravida	319	83.9
History of macrocosmic baby (n=319)	Yes	71	22.2
	No	248	77.8
History of still birth (n=319)	Yes	45	12.1
	No	274	72.1
History of abortion (n=319)	Yes	67	21
	No	252	79
History of caesarean section (n=319)	Yes	60	18.8
	No	259	81.2
History of GDM (n=372)	Yes	19	5.9
	No	300	94.1
Family history of type II DM (n=380)	Yes	57	15
	No	323	85

3.3. Obstetric characteristic of participants

Concerning basic obstetric characteristics, GDM Screening was carried out at 12-32 gestational weeks. Nearly one-third of the respondents, 247(65%) had two or more pregnancies, with mean gestational age of 25 weeks. Half of the respondents, 187(49.2%) were multi-para. Of 380 pregnant women, 53(13.9%) and 43(11.3%) had history of stillbirth and history of abortion, respectively while caesarean section rate was 56 (14.7%) (Table 2).

3.4. Medical and drug history of participants

Other medical and drug histories of the participants were assessed. Among a total respondent, 32 (8.4%) had history of GDM in the family, 21 (5.5%) had history of type 2 diabetes mellitus in the family, 87 (22.9%) have history of systolic/diastolic blood pressure (Table 2).

3.5. Magnitude of gestational diabetes mellitus

A total of 27 women were diagnosed for gestational diabetes mellitus. This according to 2017 International Association of Diabetes and Pregnancy Study Group (IADPSG) diagnostic criteria resulted in a GDM prevalence of 7.1% with 95% CI (5.3, 9.1) with a mean of 0.42 and standard deviation of ±0.48 (Figure 1).

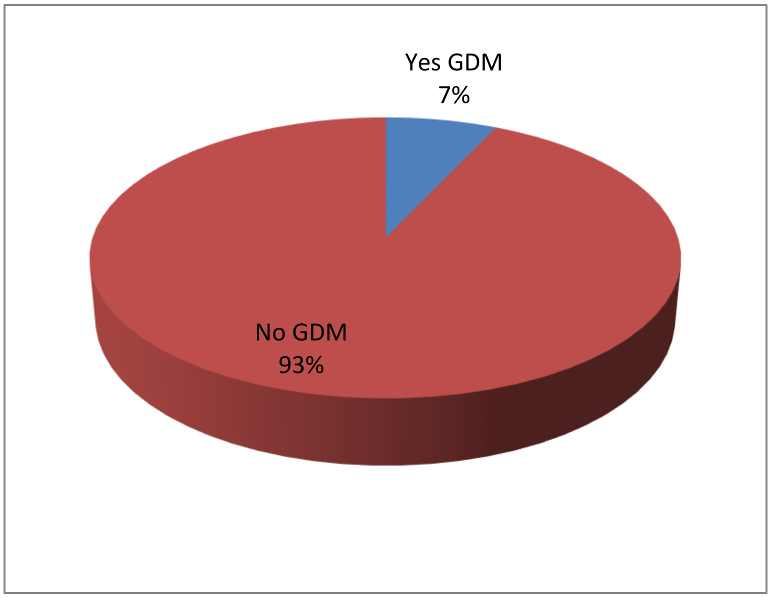

Figure 1. Prevalence of gestational diabetes mellitus among pregnant women who attend antenatal care service in public health institutions in Arba Minch town, Southern Ethiopia, 2020.

3.6. Risk factors associated with gestational diabetes mellitus

Binary logistic regression model was used to identify factors associated with GDM. Accordingly, maternal age, marital status, educational level, family size, level of physical activity, parity, history of having macrocosmic baby, history of abortion, previous history of GDM and family history of type II DM were associated with GDM.

In a multivariate logistic regression model, macrosomic baby (AOR: 1.88; 95% CI: (1.11,2.45)), educational level (AOR:2.0; 95%CI: 1.42–2.81), maternal age (AOR: 1.78; 95%CI: 1.11,2.45), parity (AOR: 2.02; 95%CI: 1.41,2.13), previous history of GDM (COR: 1.5; 95%CI: 1.11, 2.03), family history of type II diabetes mellitus (COR:2.22; 95%CI: 1.48,3.20) were identified to be significantly associated with GDM (Table 3).

Table 3. Factors associated with GDM among pregnant women who attend antenatal care service in public health institutions in Arba Minch town, Southern Ethiopia, 2020.

Variables		Non-GDM N	GDM N	COR (95% CI)	P - value	AOR (95% CI)	P-value
Maternal Age	19-25	213(98.2)	4(1.8)	1	<0.00	1	0.026
	26-35	127(92.7)	10(7.3)	0.55(0.35, 0.85)		1.24(0.01,2.47)	
	>35	13(50.0)	13(50.0)	0.38(0.29, 0.52)		1.78(1.11,2.45)	
Marital Status	Married	313(96.3)	12(3.7)	1	0.673	1	0.328
	Not married	27(67.5)	13(32.5)	0.74(0.51, 0.07)		1.01(0.73,2.19)	
	Divorced	9(81.8)	2(18.2)	0.98(0.35, 2.69)		0.56(0.30,1.39)	
Educational level	No formal education	113(91.1)	11(8.9)	1	<0.05	1	<0.0001
	Primary	122(93.8)	8(6.2)	1.4 (1.07, 1.84)		1.1(0.23, 2.06)	
	Secondary	45(90)	5(10)	1.59(1.18, 2.15)		1.5(1.02,2.21)	
	College and above	73(96.0)	3(4.0)	1.74(1.33, 2.28)		2 (1.42–2.81)	
Family size	Up to 5 members	255(94.4)	15(5.6)	1	0.10	1	0.96
	>5 members	98(89.0)	12(11.0)	0.91(0.55, 2.34)		1.14(0.02,2.47)	
Parity	Nulliparous	61(95.3)	3(4.7)	1	<0.01	1	0.0028
	Primipara	64(92.7)	5(7.3)	1.09(0.82, 1.45)		2.02(1.41,2.13)	
	Multipara (2-4)	182(93.8)	12(6.2)	1.49(0.71, 1.99)		1.52(0.75,2.23)	
	Grand multipara (>5)	46(86.8)	7(13.2)	1.81(0.85, 2.20)		2.95(1.66,3.68)	
History of macrocos mic baby	Yes	52(73.2)	19(26.8)	1	<0.00	1	<0.002
	No	240(96.8)	8(3.2)	2.07(1.52, 2.62)		1.88(1.11,2.45)	
History of still Birth	Yes	38(84.4)	7(15.6)	1	2.76	1	0.35
	No	254(92.7)	20(7.3)	1.06(0.60, 1.51)		0.91(0.48,1.49)	
Abortion history (n=372)	Yes	57(85.1)	10(14.9)	1	0.83	1	0.79
	No	235(93.2)	17(6.8)	0.87(0.10, 1.63)		0.89(0.05,1.70)	
History of caesarean	Yes	54(90.0)	6(10.0)	1	1.04	1	0.47
	No	238(91.9	21(8.1)	0.93(0.04, 1.82)		1.6 (1.10, 2.32)	
History of GDM	Yes	16(84.2)	3(15.8)	1	<0.01	1	0.003
	No	276(92.0)	24(8.0)	1.5(1.11, 2.03)		3.6 (2.25,5.20)	
Family history of type II DM	Yes	45(78.9)	12(21.1)	1	0.025	1	<0.001
	No	308(95.3)	15(4.7)	2.22(1.48,3.20		1.9 (1.11, 2.18)	

GDM=Gestational diabetes mellitus, AOR=Adjusted odd ratio, COR=Crude odd ratio

4. Discussion

This study was conducted to determine the prevalence of GDM and associated factors among women attending antenatal care at Arba Minch town, Southern Ethiopia. The prevalence of diabetes mellitus in this study was 7.1% with 95% CI (5.3, 9.1), which was higher than the studies in rural northern Ethiopia (3.7%) (Seyoum et al., 1999). This discrepancy was due to study setting and study design difference. The later study was conducted in rural area of northern Ethiopia where the predisposing factor for gestational diabetes mellitus was relatively lower. In contrast to our study, the result of study conducted in Southern Nation Nationality People Region was higher (26.2%) (Eskinder et al., 2019). The difference may be due to utilization of improved diagnosis technique, variation in residency and difference in participant’s trimester.

Pregnant women who attended college and above had two-fold less odds of developing of the problem during the pregnancy at the moment. This finding was in line with those of studies in Gondar town public health facilities, Northwest Ethiopia (Achenefi et al., 2019). Pregnant women who were grand multipara had three times more chance to develop GDM than nulliparous. This finding was inconsistent with evidence in Hadiya Zone public Hospitals (Yilma et al., 2020). This might be because of the similarity in living standards and lifestyles of the families sharing the related risk factors and demographics distribution of families.

Pregnant women with previous history of macrocosmic baby had two times higher GDM than their counterparts. Women with previous history of GDM had three times higher GDM compared to women without history of GDM while women with family history of type II DM were two times more likely to develop GDM than their counterparts. This finding was not consistent with the study conducted in Tigray region, northern Ethiopia but, the result was strongly supported by other studies conducted in southern and northern, Ethiopia (Eskinder et al., 2019; Achenefi et al., 2019). The reason for inconsistency could be explained by the difference in the study population since the result of study in Tigray region was among pregnant women living with HIV/AIDS and additionally the study setting includes rural residents and was conducted in health centres only.

5. Conclusion

The overall prevalence of diabetes mellitus was 7.1%. Older ages, low educational level, grand multipara, having macrosomic baby and history of type II diabetes mellitus were factors associated with increased risks of gestational diabetes mellitus. To enhance maternal and child health, improving screening, treatment, and prevention strategies for gestational diabetes mellitus is necessary.

Ethical approval and consent to participate

Ethical clearance was obtained from Arba Minch University College of Medicine and Health Sciences to conduct the study. Zonal administrative of Gamo Zone Health departments was communicated for support letters and different facilitation of data collection was communicated for administrative support. Written consent was obtained from the respondents and confidentiality was assured for any information provided. The right of the respondent to withdraw from the interview or not to participate is respected. In case pregnant women with complicated gestational diabetes found during data collection time, the data collector communicated with the physicians and appropriate treatment was given.

Acknowledgment

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Conflict of Interest

All authors have no financial, personal or other conflict of interest.

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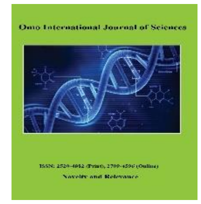

Research Article

Evaluation of blended fertilizer rates for improved sorghum [*Sorghum bicolor*, (L.) Moench.] yield in derashe district, southern Ethiopia

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Abstract

Sorghum is one of the main grains grown in Derashe district, southern Ethiopia. However, its production is limited by many factors. Of these, less fertile soil is predominant. In the region, the rational use of fertilizers has not been studied. In addition, the type of fertilizer required and the optimal fertilizer rate for the area have not been quantified. Field trials were carried out in Derashe district to evaluate the ratio of compound fertilizers to improve sorghum yield. The treatments were laid out in a Randomized Complete Block Design, with three replications, using Melkam sorghum variety. The experiment had thirteen treatments consisting of control (no fertilizer), four different types of blended fertilizers (NPS, NPSB, NPSZn and NPSZnB) each with three rates. Our analysis show that the highest grain yield was recorded from the plot that receive 225 kg·ha-1 NPSZnB + 117 kg·ha-1 urea in the first year, In the second year, the highest yield was recorded from the plot that received 150 kg·ha-1 NPS + 88 kg·ha-1 urea. In both years, the lowest grain yield was measured from the plots treated with no fertilizer (control). The marginal analysis showed that application of 112 kg·ha-1 NPSZnB + 59 kg·ha-1 urea is economically the most profitable than the other treatments. Based on our findings, it is recommended to apply 112 kg·ha-1 NPSZnB + 59 kg·ha-1 urea for the profitable production of Melkam sorghum variety in the study area.

Keywords: Grain yield; Melkam variety; Optimum fertilizer rate; Soil fertility lose

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1. Introduction

Sorghum [*Sorghum bicolor*, (L.) Moench.) is grown as one of the major food cereals in Ethiopia. The crop is the second, after maize, most cultivated crop in total production (CSA, 2011). It is well adapted to a wide range of precipitation and temperature regimes. Sorghum crop drought tolerance and adaptation attributes have made it the favorite crop in drier and marginal areas (Shiferaw and Yoseph, 2014). The crop is a staple food in South Omo and Segen area

People's zones, Southwest Ethiopia. The region is characterized as hot arid and semi-arid agro-ecological class and known for recurrent droughts (Habte *et al*., 2020). It is utilized in various forms such as for making local bread (*Injera*) and for the preparation of local alcoholic beverages such as *Tela* and *Areke*. It is also consumed as roasted and boiled grain. Sorghum stover is used as feed for animals and as housing and fencing material (Shiferaw & Yoseph, 2014). Though the crop is very important for smallholder farmers in Ethiopia, it is characterized by poor crop performance and low yields. Low soil fertility is among the major challenges for the low sorghum yield (Amelework *et al*., 2016).

Despite the low soil fertility status, in Ethiopian agriculture, fertilizer applications have been focused only on nitrogen and phosphorous fertilizers. Those fertilizers are in the form of Di-ammonium phosphate (DAP) and Urea or blanket recommendation for the major food crops. In this regard, the other essential macro and micronutrients have been neglected (Melkamu et al., 2019). Besides, in the country, there has been unbalanced use of fertilizers resulting in soil fertility lose and plant nutrient imbalances (Hordofa, 2020; IFDC, 2015).

The Ethiopian Soil Information System (EthioSIS) has conducted soil fertility mapping to identify deficient soil nutrients in Ethiopian soils (Ethio-SIS, 2016). EthioSIS also suggested fertilizer recommendations for the different districts of the country based on the soil fertility mapping results. The soil map dataset revealed that most of the nutrients are deficient in Ethiopian soils. The same applies to our study area. Therefore, the present study was designed to evaluate the appropriate blended fertilizer type and determine the optimum blended fertilizer rates for sustainable production of sorghum in Derashe district. Accordingly, we conducted field trials on different blended fertilizer rates in two consecutive seasons during 2018 and 2019.

2. Materials and Methods

2.1. Description of the study area

The experiment was conducted in Derashe district (5° 06' N latitude and 37° 30' E longitude), which is located in the Southern Nations, Nationalities and Peoples Regional State (SNNPRS). The experiment was conducted for two consecutive years under rain fed condition during the main season of 2018 and 2019. The mean annual rainfall in the area ranged from 600-1600 mm. The agro-climatic condition of the study area is categorized as *Dega* (cold), *Woyina-dega* (moderate) and *Kola* (warm) with 17.2%, 34.2% and 48.6%, respectively. The area has bimodal rainfall climatology that the major rainy season is the *belg* season during March to May. The small rain received during September to November.

2.2. Soil sampling and analysis

Prior to sowing, soil samples were collected from the experimental field. The samples were collected from the surface (0–40 cm). The samples were thoroughly mixed, air dried and grinded to pass through a 2 mm sieve to analyze and quantify the soil physicochemical parameters. Soil parameters such as soil texture, soil pH, organic carbon, total nitrogen, available phosphorus, available sulfur, and Cation exchange capacity (CEC) were the analyzed.

2.3. Experimental treatments design and procedures

The Melkam sorghum variety was used for the study. The experiment consisted of four (NPS, NPSB, NPSZn and NPSZnB) blended fertilizers each with three levels and control treatment. The treatments details are listed in (Table 1).

Table 1. Description of treatments, fertilizer type, rate and their composition

No.	Treatments ($kg \cdot ha^{-1}$)	Rate of individual nutrient ($kg \cdot ha^{-1}$)				
		N	P_2O_5	S	Zn	B
1	Control	0	0	0	-	-
2	100 NPS + 59 urea	46	38	7	-	-
3	150 NPS + 88 urea	69	57	10.5	-	-
4	200 NPS + 171 urea	92	76	14	-	-
5	105 NPSB + 59 urea	46	38	7	-	0.71
6	158 NPSB + 88 urea	69	57	10.5	-	1.06
7	211 NPSB + 171 urea	92	76	14	-	1.42
8	109 NPSZn + 59 urea	46	38	7	2.4	-
9	164 NPSZn + 88 urea	69	57	10.5	3.6	-
10	218 NPSZn + 171 urea	92	76	14	4.8	-
11	112 NPSZnB + 59 urea	46	38	8.18	2.5	0.75
12	168 NPSZnB + 88 urea	69	57	13.08	3.75	1.1
13	225 NPSZnB + 171 urea	92	76	16.36	5	1.5

The treatments were arranged in randomized complete block design (RCBD) with three replications (Gomez et al., 1984). The whole dose of blended fertilizers as source of N, P, S, Zn and additional N from urea to reach the half rate of N were applied at sowing time. The remaining half of N from urea was applied at knee height of the crop. Borax was applied in foliar as source of B. The spacing between the blocks and plots were 1m and 1m, respectively. The seeds were drilled in to rows of 0.75m apart and then thinned at the spacing of 0.2m.

All crop management practices were applied as recommended. Agronomic data such as panicle length, plant height, biomass yield, grain yield and 1000 seed weight were collected. The collected data were subjected to analysis of variance, using the SAS statistical software version 9.0 (Littell et al., 1996). And mean comparisons for the significantly different variables among treatments were made using Least Significant Differences (LSD) test at 0.05 level of significance. Economic analysis was done following the CIMMYT partial budget analysis procedure (Program et al., 1988). Total variable costs (TVC), gross benefit (GB), net benefit (NB), marginal cost (MC) and marginal benefit (MB) were calculated. After calculating MC and MB, the dominated treatments are identified. Following this, the marginal rate of return (MRR in %) was calculated for the treatments that are not dominated.

3. Results and Discussion

3.1. Soil test results

The official laboratory analysis results indicated that proportions of soil particle size distribution were 40% sand, 10% silt and 50% clay with clay loam textural class. The soil pH at the experimental site was 8.87. Soils having pH above 8 are categorized as strongly alkaline (Tadesse *et al*., 1991). The organic carbon (OC) and total nitrogen (TN) were 2.14 and 0.17%, respectively. These can rated moderate (Tadesse *et al*., 1991). The experimental soil contains 28.39 mg kg^{-1} available P, which can be rated as optimum (Ethio-SIS, 2016). The cation exchange capacity was 66.6 cmol (+) Kg^{-1} which is categorized as very high (Hazelton & Murphy, 2007). The soil contains 2.28 mg kg^{-1} S which can be taken as deficient (Ethio-SIS, 2016).

3.2. Plant height and panicle length

The results of ANOVA showed that blended fertilizer rates did not bring significant variation on plant height of sorghum in the first year. Similarly, plant height did not show significant variation in the second year with the application of different treatments except for the control treatment that lowered significantly from the others. The highest plant height was recorded from plots that receive 225 $kg \cdot ha^{-1}$ NPSZnB + 171 $kg \cdot ha^{-1}$ urea and 150 $kg \cdot ha^{-1}$ NPS + 88 $kg \cdot ha^{-1}$ urea in the first and second years, respectively. On the other hand, the lowest plant height was recorded from the control treatment (Table 2). This result substantiates that the soil analysis the area is deficient in nutrients such as S. The application of blended fertilizers resulted in an increase in plant height. In agreement with this, Wako and Usmane, (2020) reported the increment of plant height with the application of blended fertilizer over untreated ones. Application of different rates of blended fertilizers significantly increased panicle length over the control treatment but the other treatments are statistically similar with each other in both years. Though all treatments are statistically similar, the highest panicle length was measured from the plot that received 200 kg·ha^{-1} NPS + 171 kg·ha^{-1} urea in the first year. The application of 105 kg·ha^{-1} NPSB + 59 kg·ha^{-1} urea and 168 kg·ha^{-1} NPSZnB + 88 kg·ha^{-1} urea resulted with the highest panicle length (28.3 cm) in the second year. The lowest panicle length was recorded from the control in both years. This result is in line with the findings of Gebremeskel *et al*., (2017) who reported the increment of panicle length of two sorghum verities with application of blended fertilizers over the control.

Table 2. Plant height and panicle length of sorghum as influenced by different rates and types of blended fertilizers in Derashe district.

Treatments (kg·ha^{-1})	Plant height (cm)		Panicle length (cm)	
	2018	2019	2018	2019
Control	127.0^{b}	167.6^{b}	18.7^{d}	25.3^{b}
100 NPS + 59 urea	136.1^{ab}	174.0^{ab}	22.0^{abc}	27.6^{ab}
150 NPS + 88 urea	144.0^{a}	181.6^{a}	23.4^{ab}	27.3^{ab}
200 NPS + 171 urea	144.6^{a}	177.6^{ab}	24.0^{a}	28.0^{ab}
105 NPSB + 59 urea	138.6^{ab}	175.6^{ab}	22.2^{abc}	28.3^{a}
158 NPSB + 88 urea	134.9^{ab}	172.3^{ab}	21.1^{abc}	27.0^{ab}
211 NPSB + 171 urea				
CV	5.9	4.0	8.4	7.0
LSD (%)	13.7	12.2	2.9	2.9

Means within a column followed by same letter are not significantly different from each other at P ≤ 0.05; LSD = least significant difference; CV = coefficient of variation

3.3. Thousand seed weight, biomass yield and grain yield

The analysis of variance showed no significant difference for thousand seed weight of sorghum due to the treatments effect in both years (Table 3). The current result disagrees with previous work of Gebremeskel *et al*. (2017) who reported significant variation of thousand seed weight of sorghum with the application of different types of blended fertilizer on sorghum varieties. Biomass yield was significantly affected by the treatments in the first year whereas the difference in biomass yield with the application of treatments is statistically not significant in the second year. The highest biomass yield (10756 kg·ha^{-1}) was recorded from plots that received the highest amount of NPSZnB and 171 kg·ha^{-1} urea. The lowest biomass yield (7437 kg·ha^{-1}) was recorded from the control treatment. In line with this finding, Gebremeskel *et al*. (2017)

showed increased biomass yield with the application of NPSZn blended fertilizer. Choudhary *et al*. (2017) also reported that combined application of micronutrients (Fe + Zn + B) significantly increased biological yield (17.42 %) and grain yield (25.33 %) of sorghum over the control. Melaku *et al*. (2018) reported the increment of biomass yield with increasing rate of N application.

Our results showed significant effect of treatments on grain yield on sorghum in both years. The highest grain yield was recorded from the plot that received 225 kg·ha^{-1} NPSZnB + 117 kg·ha^{-1} urea in the first year, whereas it was from the plot that received 150 kg·ha^{-1} NPS +88 kg·ha^{-1} urea in the second year. The lowest grain yield was measured from the plots treated with no fertilizer (control) in both years.

Table 2. Plant height and panicle length of sorghum as influenced by different rates and types of blended fertilizers in Derashe district.

	Plant height (cm)		Panicle length (cm)	
Treatments (kg·ha^{-1})	2018	2019	2018	2019
Control	127.0^{b}	167.6^{b}	18.7^{d}	25.3^{b}
100 NPS + 59 urea	136.1^{ab}	174.0^{ab}	22.0^{abc}	27.6^{ab}
150 NPS + 88 urea	144.0^{a}	181.6^{a}	23.4^{ab}	27.3^{ab}
200 NPS + 171 urea	144.6^{a}	177.6^{ab}	24.0^{a}	28.0^{ab}
105 NPSB + 59 urea	138.6^{ab}	175.6^{ab}	22.2^{abc}	28.3^{a}
158 NPSB + 88 urea	134.9^{ab}	172.3^{ab}	21.1^{abc}	27.0^{ab}
211 NPSB + 171 urea	142.8^{a}	175.6^{ab}	22.4^{abc}	26.6^{ab}
109 NPSZn + 59 urea	128.0^{b}	176.3^{ab}	20.6^{bc}	26.3^{ab}
164 NPSZn + 88 urea				
218 NPSZn + 171 urea				
CV	5.9	4.0	8.4	7.0
LSD (%)	13.7	12.2	2.9	2.9

Means within a column followed by same letter are not significantly different from each other at $P \leq 0.05$; LSD = least significant difference; CV = coefficient of variation

3.3. Thousand seed weight, biomass yield and grain yield

The analysis of variance showed no significant difference for thousand seed weight of sorghum due to the treatments effect in both years (Table 3). The current result disagrees with previous work of Gebremeskel *et al*. (2017) who reported significant variation of thousand seed weight of sorghum with the application of different types of blended fertilizer on sorghum varieties. Biomass yield was significantly affected by the treatments in the first year whereas the difference in biomass yield with the application of treatments is statistically not significant in the second year. The highest biomass yield (10756 kg·ha^{-1}) was recorded from plots that received the highest amount of NPSZnB and 171 kg·ha^{-1} urea. The lowest biomass yield (7437 kg·ha^{-1}) was recorded from the control treatment. In line with this finding, Gebremeskel *et al*. (2017) showed increased biomass yield with the application of NPSZn blended fertilizer. Choudhary *et al*. (2017) also reported that combined application of micronutrients (Fe + Zn + B) significantly increased biological yield (17.42 %) and grain yield (25.33 %) of sorghum over the control. Melaku *et al*. (2018) reported the increment of biomass yield with increasing rate of N application.

Table 3. Thousand seed weight, biomass yield and Grain yield of sorghum as influenced by different types of blended fertilizers in Derashe district.

Treatments (kg·ha^{-1})	**Thousand seed weight (g)**		**Biomass yield (kg·ha^{-1})**		**Grain yield (kg·ha^{-1})**	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**
Control	18.0	25.6^{a}	7437.0^{d}	11454.0^{a}	1266.7^{d}	2094.0^{b}
100 NPS + 59 urea	17.6	29.6^{a}	8741.0^{abcd}	13134.0^{a}	1866.7^{abcd}	2563.0^{ab}
150 NPS + 88 urea	21.6	27.3^{a}	9956.0^{abc}	12588.0^{a}	1955.7^{ab}	3844.0^{a}
200 NPS + 171 urea	22.0	27.3^{a}	10074.0^{abc}	10450.0^{a}	1896.0^{abc}	2562.7^{ab}
105 NPSB + 59 urea	21.3	27.3^{a}	8504.0^{bcd}	10742.0^{a}	1570.3^{abcd}	2958.7^{ab}
158 NPSB + 88 urea	20.3	25.0^{a}	9185.0^{abcd}	11288.0^{a}	1807.3^{abcd}	2292.0^{b}
211 NPSB + 171 urea	22.0	26.0^{a}	8207.0^{cd}	9329.0^{a}	1510.7^{bcd}	2188.0^{b}
109 NPSZn + 59 urea	20.6	28.0^{a}	7733.0^{d}	12750.0^{a}	1377.7^{cd}	2813.0^{ab}
164 NPSZn + 88 urea	21.0	25.6^{a}	10696.0^{ab}	13342.0^{a}	1955.7^{ab}	2937.7^{ab}
218 NPSZn + 171 urea	22.0	23.6^{a}	10667.0^{ab}	11671.0^{a}	1985.3^{ab}	2187.7^{b}
112 NPSZnB + 59 urea	22.6	23.3^{a}	9333.0^{abcd}	10888.0^{a}	1748.0^{abcd}	2916.7^{ab}
168 NPSZnB + 88 urea	21.0	27.6^{a}	8829.0^{abcd}	9304.0^{a}	1688.7^{abcd}	3000.0^{ab}
225 NPSZnB + 171 urea	22.3	27.3^{a}	10756.0^{a}	10458.0^{a}	2133.3^{a}	2208.7^{b}
CV	9.7	18.0	14.0	27.0	20.2	30.0
LSD (%)	NS	NS	2192.8	NS	606.5	1305.0

Means within a column followed by the same letter are not significantly different from each other at $P \leq 0.05$; LSD = least significant difference; CV = coefficient of variation

Our results showed significant effect of treatments on grain yield on sorghum in both years. The highest grain yield was recorded from the plot that received 225 kg·ha^{-1} NPSZnB + 117 kg·ha^{-1} urea in the first year, whereas it was from the plot that received 150 kg·ha^{-1} NPS +88 kg·ha^{-1} urea in the second year. The lowest grain yield was measured from the plots treated with no fertilizer (control) in both years. From Table 3, it can be observed that the control treatment resulted in the lowest grain yield and other measured parameters compared to the other treatments. This substantiates that the importance of blended fertilizers to increase crop yield. The result is in concurrence with the findings of Weldegebriel *et a*l., (2018) reported that application of blended NPKSZn increased sorghum grain yield by 136.5% over the control treatment. Similarly, (Wako & Usmane, 2020) explained increased grain yield with the application of NPSZnB blended fertilizer. It is also reported that plots treated with blended fertilizers resulted in highest grain yield compared with the untreated (control) on other cereals such as maize and barley (Chimdessa, 2016; Hordofa, 2020).

3.4. Economic analysis

Economic analysis was done to evaluate the economic benefits of rates of different blended fertilizers on sorghum (Table 4). The economic analysis was done using mean of the two years grain yield data. The partial budget analysis shows that the highest net benefit was obtained from the application of 150 kg·ha^{-1} NPS + 88 kg·ha^{-1} urea followed by 164 kg·ha^{-1} NPSZn + 88 kg·ha^{-1} urea.

Table 4. Partial budget and marginal analysis of blended fertilizers on grain yield of sorghum.

Treatments (kg·ha^{-1})	**AGY (Kg·ha^{-1})**	**GB (ETB ha^{-1})**	**TVC (ETB ha^{-1})**	**NB (ETB ha^{-1})**	**MC**	**MB**	**MRR (%)**
0	1512.32	21928.57	0	21928.57	-	-	
100 NPS + 59 urea	1993.37	28903.79	2674	26229.68	2674.00	4301.12	160.85
105 NPSB + 59 urea	2609.87	37843.04	2757	26795.07	82.55	565.38	684.91
109 NPSZn + 59 urea	2006.42	29093.02	2883	24461.64	126.02	D	-
112 NPSZnB + 59 urea	2038.05	29551.73	2997	27440.12	114.38	2978.47	2604.12
150 NPS + 88 urea	1844.69	26747.93	4003	33840.06	1005.93	6399.94	636.22
158 NPSB + 88 urea	1664.42	24134.02	4135	22612.60	132.35	D	-
164 NPSZn + 88 urea	1885.82	27344.32	4325	27604.81	189.29	D	-
168 NPSZnB + 88 urea	2202.03	31929.44	4487	26106.37	162.77	D	-
200 NPS + 117 urea	1877.85	27228.83	5332	23761.16	844.46	D	-
211 NPSB + 117 urea	2099.12	30437.17	5514	18620.00	182.16	D	-
218 NPSZn + 117 urea	2109.92	30593.77	5749	21479.84	234.97	D	-
225 NPSZnB + 117 urea	1953.90	28331.55	5996	22335.67	246.89	D	-

AGY: Adjusted grain yield; GB: Gross benefit TVC: Total variable cost; NB: Net benefit; MC: Marginal cost; MB: Marginal benefit; MRR: Marginal rate of return; ETB: Ethiopian Birr.

The economic analysis showed that application of 112 kg·ha^{-1} NPSZnB + 59 kg·ha^{-1} urea is economically the most profitable than the other treatments. This treatment corresponds to the highest marginal rate of return (MRR, 2604%). This mean that for each 1 ETB additional investment on fertilizer, farmers can earn a return of 26 ETB. The next economically feasible treatment was 105 kg·ha^{-1} NPSB+59 kg·ha^{-1} urea (MRR of 685%). The analysis also showed that application of the treatments except the dominated ones gave above 100% MRR which is an acceptable rate of return (CIMMYT, 1998) (Table 4).

4. Conclusions

The results of this study showed that in the first year, all the measured parameters of sorghum except for thousand seed weight responded positively (statistically significant) to the application of the ratios. different fertilizers. Similarly, in the second year, plant height, panicle length and seed yield of sorghum responded positively (statistically significant) to the fertilization treatments. The highest grain yield was obtained from the application of 225 kg·ha^{-1} NPSZnB + 171 kg·ha^{-1} urea, in the first year. Whereas in the second year, the highest grain yield was recorded from the application of 150 kg·ha^{-1} NPS + 88 kg·ha^{-1} urea. In terms of economic feasibility, the application of 112 kg·ha^{-1} NPSZnB + 59 kg·ha^{-1} urea resulted in highest economic return. Therefore, based on our study, it is recommended to apply 112 kg·ha^{-1} NPSZnB + 59 kg·ha^{-1} in the study area and areas having the same soil and agroecological conditions.

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Conflict of the Interest

The authors declare that they have no conflict of interest.

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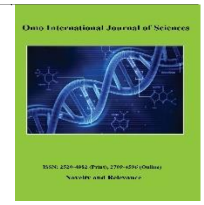

Research Article

Evaluation of *Lablab purpureus* accessions in two agro-ecologies of Benishangul-gumuz, Western Ethiopia

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Abstract

A study was conducted to evaluate *L. purpureus* accessions for their agronomic traits under two agro-ecologies of Benishangul-Gumuz region. The experiment was carried out at Assosa and Kamash forage research stations of Assosa Agricultural Research Center, They were purposively selected to represent mid and lowland agro-ecologies respectively. Four *Lablab purpureus* accessions (*L. purpureus* 147, 11609, 11640, and 6529) were evaluated in randomized complete block design with three replications. The general linear model procedures of SAS and least significance difference for data analysis and mean separation were employed respectively. Environment (E) had significant effect on plant height at forage harvesting ($P < 0.001$), forage dry matter yield ($P < 0.01$) and leaf to stem ratio ($P < 0.01$). *L. purpureus* genotypes planted at Kamash had longer plant height and dry matter yielder than Assosa, however leaf to stem ratio was higher at Assosa. Genotype (G) and G x E (G and E interaction) had no significant $P > 0.05$) effect on forage dry matter yield, plant height and leaf to stem ratio. In conclusion, environment had significant effect on forage dry matter yield, leaf to stem ratio and plant height, therefore evaluations of yield performance and adaptation patterns of *L. purpureus* genotype in multiple environments are very important step in agronomic evaluation and selection of better adapted and high yielding genotype.

Keywords: Accessions; Benishangul-Gumuz; Environment; *Lablab purpureus*

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1. Introduction

Ethiopia has huge livestock population. However, it was not possible to meet the ever-increasing demand for animal products (Sisay, 2006). In Ethiopia, livestock production is characterized by low productivity for meat production and reproductive performance. The low productivity of livestock is mainly attributed to inadequate nutrition, low genetic potential of indigenous breeds, prevalence of disease and parasites. Among these factors, under nutrition/ malnutrition is considered to be the most important limiting factors constraining animal production in Ethiopia (Adugna et al., 2000; Bekele, 2010). In almost all parts of Ethiopia, annual pasture grasses (54.6%) and crop residues (31.6%) are the main sources of feed in the country (Tolera et al., 2000; Mengistu, 2004; CSA, 2017). Indeed, in Benishangul-Gumuz regional state natural grass land which is dominated by *Hypernia* species is the major livestock feed resource. Feedstuff of such composition, natural grass and crop residue, are insufficient to provide adequate quantity and quality of nutrient beyond maintenance requirement. Therefore, improved forage development and wise utilization of crop by-products can be minimizing the problem.

Cultivated forage crops have high yielder and better quality as compared to the natural pasture. Moreover, forage legumes have high protein sources that will enhance the activity of rumen microorganisms, increase intake and digestibility when supplement for animals consuming poor quality forages. Moreover, they can contribute to soil fertility maintenance and improvement (Mosi & Butterworth, 1985; Smith et al. 1989). Growing of multipurpose forage legume crops like *lablab* through under sowing/intercropping is useful for introduction of the forage crop and to use the available small farmland for both crop and livestock feed production. Intercropping annual forage legumes with cereal crops has been proposed as a strategy to control erosion, suppress weeds and contribute biological N to companion crop (Nadeem et al, 2009). Hence with this in mind, to introduce this forge species through intercropping forage development strategy, screening of the promising accessions to that environment is mandatory. The performance of forage species varies across locations due to differences in soil types, temperature and amount and distribution of rainfall. The cultivation of high-quality forages with a high yielding ability, adaptable to biotic and abiotic environmental stresses is one of the possible options to increase livestock production under smallholder farmers conditions (Tessema, 1999). Indeed, improved forage legume crops like *L. purpureus* are one of the best forage legumes for animal feed and soil fertility improvement through biological nitrogen fixation.

L. purpureus is an erect, short-lived perennial herbaceous crop often grown as an annual (Kikafunda, 2001). It is preferred for good forage production, nutritional quality, and palatability. *L. purpureus* is also shade-tolerant so that it is suitable for intercropping. *L. purpureus* is drought tolerant, and has been grown in arid and semiarid regions (Aganga &

Tshwenyane, 2003). Currently, *L. purpureus* is one of the major leguminous forage and green manure crops. However, there are no recommended *L. purpureus* accessions for their yield and agronomic performance in Benishangul-Gumuz region. Therefore, the objective of this study was to evaluate the forage dry matter yield production potential of *L. purpures* accessions and finally select and recommend the best performing accessions for use as alternative improved forage legumes in Benishangul-Gumuz regional state (BGRS), Western Ethiopia and agro-ecologies similar to the study area.

2. Materials and Methods

2.1. Study areas

The trial was conducted under field conditions at Assosa, and Kamash forage research stations of Assosa Agricultural Research Center during the main cropping seasons. The test locations represent the mid and lowland areas ranging in altitude from 1000 to 1550 m.a.s.l. The farming system of the study areas is Agro pastoral. Descriptions of the test environments are indicated in Table 1.

Table 1. Descriptions of the test environments for geographical position

Parameters	Study sites	
	Assosa	Kamash
Latitude	10°30’N	09. °30′N
Longitude	034°20’E	35°45′E
Altitude(masl)	1500-1550	1000-1350
Annual rainfall(mm)	1316	1150
Daily minimum Temperature (^{0}C)	16.75	25
Daily maximum Temperature (^{0}C)	27.9	30

2.2. Experimental treatments and design

The four accessions of *Lablab purpureus* accessions (*L. Purpureus* 147, 11609, 11640, and 6529) were collected from ILRI. The accessions were planted in 3 m x 4 m plot using a randomized complete block design (RCBD) with three replications at the beginning of the main rainy season. Seed was sown by drilling in rows spaced 30 cm between rows, at a depth of 3 cm. Individual plot size was 12 m^2 and spacing between plots and replications 1.5 and 2 m, respectively at each testing environments. The treatments were sown according to their recommended seeding rates: 15-20 kg ha^{-1}.

2.3. Data collection

Data was collected on plant height at harvesting, leaf to stem ratio and forage dry matter yield. Plant height at harvesting was taken on six plants randomly selected from each plot and measured using a steel tape from the ground level to the highest leaf. For determination of biomass yield, accessions were harvested at 10% blooming stage using a quadrant which has $1m^2$ areas. Weight of the total fresh biomass yield was recorded from each plot in the field and 500 g sample was taken from each plot to the laboratory and a sub-sample of known fresh weight was oven-dried for 72 hours at a temperature of 65 ^{0}C to determine dry matter yield.

2.4. Statistical analysis

Analysis of variance (ANOVA) procedures of SAS general linear model (GLM) was used to analyze the quantitative data (SAS, 2002). LSD test at 5% significance was used for comparison of means. The data was analyzed using the following model:

$$Yijk = \mu + Gi + Ej + GEij + Bk + e\ ijk$$

Where, Yijk = dependent variables, μ = grand mean, Gi = effect of genotype i, Ej = effect of environment j, j = Assosa and Kamash, GEij = is the interaction effect of genotype i and environment j, Bk = effect of block k, and e ijk = random error effect of genotype i, environment j, interaction effect of genotype i and environment j, and block k.

3. Results and Discussion

3.1. Environment and interaction effect on *L. purpureus* accessions performance

Combined analysis of variance for measured agronomic traits of *L. purpureus* accessions tested over environments is presented in Table 2. Environment (E) had significant effect on plant height at forage harvesting ($P < 0.001$), forage dry matter yield ($P < 0.01$) and leaf to stem ratio ($P < 0.01$). This variation might be due to differences among the testing environments in altitude, soil types, temperature and differences in both amount and distribution of annual rainfall and other agro-climatic factors. Findings from this experiment agree with reports of Abuye et al. (2018) who findings reveal that location significantly affect the forage dry matter yield of *L. purpureus* cultivars studied for herbage yield. Genotype (G) and G x E (genotype by environment interaction) had no significant ($P > 0.05$) effect on plant height at forage harvesting, leaf to stem ratio and forage dry matter tield. Generally, the result of this study indicated that environmental factors significantly influenced the yield performance and adaptation patterns of *L. purpureus* genotype. Therefore, evaluations of yield performance and adaptation patterns of *L.*

purpureus genotype in multiple environments are very important step in agronomic evaluation and selection of better adapted and high yielding species and varieties.

Table 2. Combined analysis of variance for measured agronomic traits of four *L. purpureus* accessions tested in two agro-ecologies of Benishangul-Gumuz regional state

Traits	Mean square		G × E	Mean	Coefficient of variation (%)
	Genotype (G)	Environment (E)			
Plant height (cm)	ns	***	ns	145.21	44.09
Forage DM yield (t/ha)	ns	**	ns	4.34	36.89
Leaf to stem ratio	ns	**	ns	0.67	46.87

3.2. Leaf to stem ratio

The leaf to stem ratio at forage harvesting of tested *L. purpureus* accessions is indicated in Table 3. Environment had significant ($P < 0.01$) effect on leaf to stem ratio. The higher leaf to stem ratio was obtained from the mid-altitude (Assosa) than lowland altitude (Kamash) and this might be due the function of the longer periods of physiological growth of plants in high altitude/cooler environment with increase defoliation frequency stimulating leaf growth at the expense of stem production. The leaf to stem ratio has significant implications on the nutritive quality of the forage as leaves contain higher levels of nutrients and less fiber than stems. The result indicated that the leaf to stem ratio is an important factor affecting diet selection, quality and intake of forage (Smart et al*.*, 2004).

Table 3. Mean leaf to stem ratio of four *L. purpureus* accessions tested in two agro-ecologies of Benishangul-Gumuz regional state

Accessions	Location/Environments		Combined analysis
	Assosa	Kamash	
L. purpureus 147	0.75	0.50	0.58
L. purpureus 11609	0.86	0.46	0.59
L. purpureus 6529	0.79	0.63	0.68
L. purpureus 11640	0.74	0.62	0.66
Mean	0.79^a	0.55^b	0.63
Coefficient of variation (%)	29.12	32.63	52.33
P-value	Ns	ns	ns

The leaf to stem ratio is associated with high nutritive value of the forage because leaf is generally of higher nutritive value (Tudsri et al*.*, 2002) and the performance of animals is closely related to the amount of leaf in the diet. Therefore, according to the report of these authors the *L. purpureus* genotypes grown at Assosa is more nutritious than *L. purpureus* genotypes grown at Kamash due to the leaf to stem ratio was higher at Assosa than Kamash. The result of combined and each locations analysis showed that leaf to stem ratio was non-significant ($P < 0.05$) among the accessions.

3.3. Plant height at forage harvesting

Summary analysis of variance for the performance of different *L. purpureus* accessions on plant height at forage harvesting was given in Table 4. The result of this study revealed that testing environment significantly ($P < 0.001$) affect plant height at forage harvesting and higher value of plant height at forage harvesting recorded at Kamash. This might be associated to the difference in environmental condition such as rainfall, soil fertility, temperature. Although, the result could be due to the Assosa soil is more acidic (PH > 5.5) than the Kamash soil (PH < 5.5) and this leads to plant root growth which result stunted and reduced growth rate in plants at Assosa. The result of combined and each location analysis showed that plant height at forage harvesting was not significantly ($P > 0.05$) different among the tested genotypes.

Table 4. Mean plant height at forage harvesting (cm) of four *L. purpureus* accessions tested in two agro-ecologies of Benishangul-Gumuz regional state

Accessions	Location/Environments		Combined analysis
	Assosa	Kamash	
L. purpureus 147	114.75	172.20	153.05
L. purpureus 11609	95.92	170.69	145.77
L. purpureus 6529	145.42	194.05	177.84
L. purpureus 11640	102.00	166.65	145.10
Mean	114.52^{b}	175.90^{a}	155.44
Coefficient of variation (%)	32.47	28.00	44.51
P-value	Ns	Ns	Ns

3.4. Forage and dry matter yield

The mean forage dry matter yield of four tested *L. purpureus* accessions is presented in Table 5. The result of this study showed that forage dry matter yield of *L. purpureus* was significantly ($P < 0.01$) different among locations/testing environment. *L. purpureus* genotypes grown at Kamash provided more yield than *L. purpureus* genotypes grown at Assosa. This might be due to the leaf stem ratio of the tested *L. purpureus* accessions was higher at Assosa than Kamash. As the leaf to stem ratio increased, the forage dry matter yield decreased, however the nutrient content increased and this might be due the leaf part of the forage is more nutritious than stem. The result might be due to the forage dry matter yield is directly related to plant height at forage harvesting stage, because when the plant height at forage harvesting increases forage dry matter yield also increases. The result of combined and each location analysis showed that forage dry matter yield did not significantly (P > 0.05) affected by genotypes. Comparable value of herbage dry matter yield (4.54 t/ha) compared to this study result was reported by Bikila et al. (2017) who studied three accessions of *L. purpureus* (*L. purpureus* 11614, 147 and 11640) for their adaptation performance under the semi-arid environments of Borana zone.

Table 5. Mean forage DM yield (t/ha) of four *L. purpureus* accessions tested in two agro-ecologies of Benishangul-Gumuz regional state

	Location/Environments		
Accessions	Assosa	Kamash	Combined analysis
L. purpureus 147	3.40	4.38	4.06
L. purpureus 11609	3.27	4.98	4.41
L. purpureus 6529	4.36	5.59	5.18
L. purpureus 11640	3.90	4.81	4.51
Mean	3.73^{b}	4.94^{a}	4.54
Coefficient of variation (%)	27.68	36.57	36.76
P-value	Ns	ns	Ns

4. Conclusion

Based on the results, it can be concluded that the environment can affect plant height at forage harvesting, leaf to stem ratio and forage dry matter yield of *L. purpureus*. Lowland altitude could be most favorable agro-ecology than mid-altitude for *L. purpureus* since the plant height and forage dry matter yield is higher at lowland agro-ecology. Therefore, it can be concluded that evaluations of yield performance and adaptation patterns of *L. purpureus* genotype in multiple environments are very important step in agronomic evaluation and selection of better adapted and high yielding species and varieties.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Research Article

Effect of yoga training intervention on health-related physical fitness performance of U-17 male football project players

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Abstract

Yoga training can significantly improve multiple health-related aspects of physical fitness of female subjects. Previous research findings recommend the need to evaluate the impact of yoga in different age groups, components of fitness, and measurement tools, along with the other regular training. So this study was aimed to assess the effectiveness of yogic exercise on selected health-related physical fitness performance of U- 17 male football project players in Dilla Town. A quasi-experimental study design was carried out for 8 weeks. The study was done on 30 players by using a convenient sampling method. The measure of cardiovascular endurance, leg strength, and flexibility of each player was taken and recorded immediately before and shortly after the 8-week yogic training. The mean and standard deviation were determined by using paired sample T-test. Data were analyzed by Statistical Package for scientific solution (SPSS version 20.0). The level of statistical significance was set at $P < 0.05$. It was found that yoga exercise has a significant effect on cardiovascular endurance (10.73 ±1.1 and 12.73±0.88 level) of the yogic group but, almost no change (10.60±1.183 and 10.87±0.990) in a non-yoga group. Yoga exercise improves flexibility (3.30±0.643 and 4.60 ±0.632 cm) of the yogic group but, almost no change in (3.34±0.83 and 3.68±0.60 centimeter) non-yogic group. It also improves leg strength (35.67±3.84 and 38.60±3.24 number) of the yogic group but, almost no change (37.67±3.28 and 37.87±3.38 number) in the non-yogic group. The results of this study showed that yoga exercise has a significant effect on the flexibility, strength, and cardiovascular endurance of football players. Therefore, yoga exercises can be installed in regular football training sessions.

Keywords: Football; Health; Physical fitness; Yoga

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1. Introduction

Football is a sport that involves various skills, strategies, tactics, and physical elements which are required for improvement of a player's performance (Rosch et al., 2000). Among those, physical fitness is one of the factors that could affect football players' performance (Rosch et al., 2000) and Kadagadakai & Pradhan (2018). In football, aerobic and anaerobic abilities, speed, strength, and power are variables that significantly affect the effectiveness of worldwide football players (Turner et al., 2011).

Different training methods like skill, tactic, physical, psychological, and fitness training should be included in the training session of football trainees (Reilly, 2007) and Reilly & Williams (2003). Aside from the necessary technical and tactical skills required, football players must also develop and retain a high level of aerobic and anaerobic conditioning, speed, agility, strength, and power (Turner & Stewart, 2014).

To attain maximum physical performance, the football-specific training program is used to improve selected physical fitness variables like speed, abdominal strength, leg explosive power agility, and flexibility (Sukuma, 2018). Among specific training programs, yogic practices are one of the football-specific training which is aimed at improving playing performances (Johnson & Mariayyah, 2007).

Another study also shows that a 12-week yoga training intervention was connected with the development of health-related physical fitness ability in young healthy individuals. The yoga training program was connected with a significant decrease in relative body fat and an increase in the hamstring flexibility and abdominal endurance of an individual (Shiraishi et al., 2017). Study shows that yoga training significantly improves the measures of flexibility (Iftkher et al., 2017). Yoga training plays a significant role in improving strength, hamstring, hip, and back flexibility performance (Kumar et al., 2013).

In the yoga training program, the common activities include static stretching exercises, weight training, and running (Polsgrove et al., 2016). If the static stretch is performed for 30 seconds at a frequency of 3 repeated stretches per single training session it is enough to enhance muscle length (Anoop et al., 2012). The slow stretching; twisting, and bending movements lead flexibility to other joints and muscles of the arch and supply nutrients and oxygen to all the cells of the body (Khan et al., 2016).

Yoga training can improve muscular strength, muscular endurance, flexibility, and cardio-respiratory endurance performance (Tran et al., 2011). It is recommended that doing a static stretching routine at the end of the regular training program is appropriate, for the best results in football players' performance (Rodiguez et al. (2016). Future studies are needed to investigate the impact of yoga intervention on specific components of the fitness capacity of players in sport-specific tasks (Polsgrove et al., 2016)]. For betterment in leg strength, agility, and endurance ability long-period training programs may be more effective (Khan et al., 2016). Future study is required to do on a large sample size with different age category, other port departments, other components of fitness, and measurement tools (Iftekher et al., 2017). Taking these precedents into account the aim of this study was to examine the effect of yoga training on health-related physical performance among U- 17 male football project players in Dilla town, Southern Ethiopia.

2. Materials and Methods

2.1. Description of the study area

This study was conducted in Dilla town in Gedeo Zone, which is located in South Nations Nationalities and People Region States (SNNPRS), Ethiopia at a distance of 359 km from the capital city of Ethiopia, Addis Ababa, on the way from Addis Ababa to Moyale. It is located at 6° 22´ to 6° 42´ N and 38° 21´ to 38° 41´ E longitude with an altitude of about 1476 m above sea level.

2.2. Study design

In this study, a quasi-experimental study design was carried out from February 22, 2019, up to April 22, 2019, for 8 weeks.

2.3. Population and sample of the study

Selam hospital U-17 male football project players was taken as a source population. The project has 35 male football project players in the respective age category during the study period. Out of the 35 players, 30 players were selected by convenient sampling method, according to their availability and suitability guided by the coaches. To this end, samples were randomly assigned to the yogic group (n=15) and non-yoga group (n=15).

2.4. Variables of the study

In this study, the physical fitness components (cardiovascular endurance, muscular strength, and flexibility) were considered as dependent variables whereas, the independent variable was, the duration of training intervention (8 weeks, 3 days per week, 18 minutes per training session, and 1 up to 1½ minute per a single activity) and pattern of yoga asana.

2.5. Eligibility criteria

All U-17 male football project players, who actively play during the study period, were included in the study while new players, none volunteered players, and injured players were excluded from the study.

2.6. Yoga asana training protocol

During the period of yoga training for 8 weeks, players of both yogic and non-yogic groups have also taken part in the regularly pre-planned program for carrying out football-specific training. In addition to the regular training program, the yoga group took part in a 3-day yoga asana training session per week (Monday, Wednesday, and Thursday).

2.7. Data collection instrument

Testing and measurements are the means of collecting data upon which subsequent physical performance tests and decisions are made. The data has been collected using the pre-test and post-test on which the tests were performed between 9 AM and a couple of PM.

2.8. Sequence of testing

All football-specific field tests were performed sequentially with increasing performance tests inducing fatigue. So a test began with highly skillful testing tasks to tests that are inducing fatigue so that the latter does not distort the results. Therefore this study performed a test beginning from sitting and reaching to assess lower back and hamstring flexibility, a sergeant jump test to assess elastic leg strength and to beep test to assess cardiovascular endurance (Turner et al., 2011). The tests were performed on a natural grass football pitch.

2.9. Protocol of beep test

This test involves continuous running between 2 lines that were marked 20 m apart in time to record beeps. The players stood behind the starting line marks that face the 2nd line, and begin running when instructed by the recorded beeps. The speed at the tart is fairly slow. The players continued running between the two lines, turning when signaled by the recorded beeps. After about one minute, a beep sound indicates each minute. If the line is reached before the beep sounds, the players must wait until the beep sounds before continuing. If the road is not reached before the beep sound the individual is given a warning and must still to the road, then turn and check out to catch up with the pace within two more beeps. The subject was given a warning the first time they fail to reach the line (within 2 meters) and eliminate after the second warning (Wood, 2008).

2.10. Sit and research the test

This study has employed this test to assess the lower back and hamstring flexibility of football project players. The sit and reach test was carried out as follows. At the start of a test, the players were sitting on the ground with shoes removed, feet flat against the table, and legs straight. Then the players bend and reach forward and push the fingers along the table as far as possible. The distance from their fingertips to the margin of the table represents the score for that player. It is important to possess several warm-up attempts first and to record an excellent score.

2.11. Sergeant jump test

This study was assessing leg strength through the sergeant jump test. The objective of this test is to assess leg strength performance. The test is conducted as follows: the players apply chalk at the end of their fingertips. Then stands side onto the wall, keeping both feet remaining on the ground, reaches up as high as possible with one hand, and ticks the wall with the tips of the fingers (T1). From a static position jumps as high as possible and ticks the wall with the chalk on his fingertips (T2). We measure the distance from T1 to T2. The test can be performed as many times as the player wishes.

2.12. Method of data analysis

The pre-test and post-test results were analyzed using a statistical package for scientific solution (SPSS) version 20.0 by paired sample T-test to compare means and statistical significance differences of the test. Statistical significance was declared at a 95% confidence interval with P-values $p < 0.05$.

3. Results and Discussion

3.1. Socio-demographic characteristics

A total of 30 U-17 football players were enrolled in this study. Out of the total respondents, all 30(100.0%) were aged 16 (Table 1).

Table 1. Socio-demographic characteristics of study subjects (n=30)

Variables	Category	Frequency (%)
Socio-demographic	16 years	30(100.0)

3.2. Analysis of pretest and posttest of the control and experimental groups

Both the yoga and non-yoga group of this study was actively trained U- 17 football player. Although they were active enough, they were not undergone such a scientific approach to measure their physical fitness status. This study found out what their actual fitness level looks like by using a scientific fitness testing approach as it was used by previous researchers. After all, this study evaluated the player's physical fitness level of both the yogic group and non-yogic group and thus resulted as follows.

3.3. Analysis of health-related physical fitness profiles (Experimental group)

There were 3 variables in the health-related fitness assessment of the players that had a P value of less than 0.05. The pre and post-test mean and SD scores of sit and reach test of the yoga group were 3.30±0.643 and 4.60 ±0.632 cm respectively, which was statistically significant (P <0.05, P=0.00). (See table 2). This indicates that two-month yoga training has caused an increase in the lower back and hamstring flexibility of the players. As shown in Table 2, the pre and post-test mean and SD scores of the beep test of the yogic group were 10.73 ±1.1 and 12.73±0.88 levels respectively, which was statistically significant(P=0.001). This indicates that yoga training improves the cardiovascular endurance of players. The pretest and post-test mean scores of the sergeant jump test of the yogic group were 35.67±3.84 and 38.60±3.24 cm respectively, which was statistically significant (P=0.001). This indicates that yoga asana training enhances the leg strength of the players.

Table 2. Comparison of selected health-related physical fitness variables of experimental groups

Variables	Group	Test (Mean ± S.D)		P-value
		Pre-test	Post-test	
Flexibility (sit and reach in cm)	Experimental	3.30±0.643	4.60 ±0.632	0.001
Cardiovascular Endurance (beep test)	Experimental	10.73 ±1.1	12.73±0.88	0.001
Leg Strength (sergeant jump test in cm)	Experimental	35.67±3.84	38.60±3.24	0.001

3.4. Analysis of health-related physical fitness profile (Control group)

The pre and post-test mean and SD scores of sit and reach test of the non-yoga group were 3.34±0.83 and 3.68±0.60 cm respectively. No significant difference (P=0.205) was found among the non-yoga group who performed the same test. This indicates that there is no improvement in the lower back and hamstring flexibility of the players having regular forms of football training but not yoga training (Table 3). The pre and post-test mean and SD scores of the beep test of the non-yogic group were 10.60±1.183 and 10.87±.990 levels respectively, which was statistically insignificant (P=0.509). This indicates almost no changes in the cardiovascular endurance of players. The pretest and post-test mean scores of the sergeant jump test of the non-yogic group were 37.67±3.28 and 37.87±3.38cm respectively, which was statistically insignificant (P=0.77). This indicates no change, in the leg strength of the players.

Table 3. Comparison of selected fitness variables for pre-test and post-test for non-yoga groups

Variables	Group	Test (Mean ± S.D)		P-value
		Pre-test	Post-test	
Flexibility (sit and reach in cm)	Control	3.34±0.83	3.68±0.60	0.205
Cardiovascular Endurance (beep test)	Control	10.60±1.183	10.87±.990	0.509
Leg Strength (Squat in number)	Control	37.67±3.28	37.87±3.38	0.770

Regular practice of yoga has numerous health benefits (McDermott et al. (2014) and Aktar et al. (2013). Yoga also brings positive changes in physical performance and well-being if practiced regularly (Ross & Thomas, 2010); Boehde et al., 2005) by improving flexibility and balance (Johanson & Mariayyah, 2007; Polsgrove et al., 2016) as well as cardiovascular functions (Polsgrove et al., 2016; Bera & Rajapurkar, 1993). Moreover, yoga may have a direct link to improving the common elements of athletic performance.

The findings of the present study have strongly indicated that the yoga asana exercise of 8 weeks has shown significant improvement in cardiovascular endurance, leg strength, the flexibility of football players. The potential for hamstring injury during placekicking tasks about muscle length and range of motion. Joint flexibility is a crucial factor in soccer. Testing for limitations in the range of motion at a joint can be of benefit in screening for injury predisposition (Reilly & Williams, 2003).

The pre-test and post-test mean of lower back and hamstring flexibility were 3.30 and 4.60 cm respectively in the yoga group have a significant improvement (P=0.001). In contrast, non-yoga group, there is no significant improvement in their performance. The pre-test and post-test scores were3.34±0.83 and 3.68±0.60 cm respectively for a non-yoga group with (P=0.205).

This finding is consistent with studies conducted in different parts of the world. Our study finds similarities with other studies conducted for about 10 and above weeks of a yoga session in a similar setting, significantly higher improvement was seen in flexibility in Chicago: North America (Polsgrove et al., 2016), and India (Swami & Patil, 2016; Yuvaraji, 2016). This might be due to the lower duration of training that our study employed. Our study of lower back and hamstrings flexibility improvement was higher than in other studies conducted in India, Bangladesh: Asia (Iftekhr et al., 2017); Turkey (Kartal & Ergin, 2020). This might be due to variations in study duration, and demographic characteristics of participants of the study, those studies employed a lower duration of training less than or equal to 6 weeks.

However, this is inconsistent with other studies conducted among Olympic weightlifters revealed that the 7 weeks of yoga training did not show significant differences between the yoga and nonyoga groups of players in flexibility measures (Ernst & Jensen, 2016), which is not agreed with the finding of our research. A possible explanation may be that the research was assessed using an inappropriate sequence of fitness testing. Hence, excluding only evidence from one research, we can surely recommend including yoga asana sessions along with the regular training programs is important in increasing the players' performance.

Various field tests for aerobic capacity are trend-upwards that need the players to either cover a maximal distance during a set time or a distance having made a firm decision within the short time possible. The beep test aimed at predicting aerobic capacity is often advised for football. The pre-test and post-test mean scores of the beep test were 10.73 and 12.73 in level respectively for the yogic group which has a significant effect on ($P=0.001$) cardiovascular endurance of football players. In contrast, in non-yoga groups, the pre-test and post-test mean of the beep test are 10.60 ± 1.183 and $10.87\pm.990$ in level respectively, which has no significant effect ($P=0.509$) on the cardiovascular endurance of football players having regular forms of football training but not yoga training. Other studies also show that yoga training can increase the cardio-respiratory endurance of students (Yadav & Malik, 2015; Kaur, 2016; Yuvaraj, 2016). This indicates that 8-week yoga asana training is used to improve the cardiovascular endurance performance of football players.

Strength in the lower limbs is of obvious concern in soccer: the quadriceps and hamstrings must generate high forces for jumping, kicking, tackling, turning, and changing pace. Due to the predominance of leg musculature during football we use the sergeant jump test to test leg strength. The pre and post-test mean scores of the sergeant jump test were 35.67 ± 3.84 and 38.60 ± 3.24 cm respectively, which has significant improvement ($P <0.05$, $P=0.00$) in leg strength. In contrast, in the non-yogic group, the pre and post-test mean scores of the sergeant jump test were 37.67 ± 3.28 and 37.87 ± 3.38cm respectively which have no significant difference ($P> 0.05$, $P=0.77$) in leg strength. This indicates that an 8-week yoga asana training intervention is used to improve the leg strength of football players. This is consistent with another study

(Boss & Thomas, 2010; Yadav & Malik, 2015; Kartal & Ergim, 2020), which employed different testing tools to assess the leg strength of football players.

4. Conclusion

Based on the finding of this study, taking part in a yoga training session with regular football training methods can help to improve the physical performance of football players. Additionally, the results of this study showed that yogic practice has a significant effect on flexibility, strength, and cardiovascular endurance.

Ethics Approval and Consent to Participate

The study was conducted by the ethical guidelines of Dilla University. Adequate information was provided to the research participants and their parents, participation in the research was also freely volunteered, with the understanding that the participant can withdraw at any time, consent with clear language was given at a level that the child can understand and in addition, informed consent was obtained from their parents and guardians for the study participation. All participants were informed orally and in writing about the study's purpose, risks, and benefits, and signed a written informed consent before being allowed to participate in the intervention. The intervention protocol was checked and approved by a research review committee of the Sports Science department at Dilla University.

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Competing Interests

The authors declare that they have no conflicts of interest.

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